



**HAL**  
open science

## Continuous recording of resistivity with towed arrays for systematic mapping of buried structures at shallow depths

Michel Dabas, Jean-Paul Décriaud, Georges Ducomet, Albert Hesse, Abdo Mounir, Alain Tabbagh

### ► To cite this version:

Michel Dabas, Jean-Paul Décriaud, Georges Ducomet, Albert Hesse, Abdo Mounir, et al.. Continuous recording of resistivity with towed arrays for systematic mapping of buried structures at shallow depths. *Archeosciences, revue d'Archéométrie*, 1994, 18, pp.13-17. hal-02926337

**HAL Id: hal-02926337**

**<https://hal.science/hal-02926337>**

Submitted on 31 Aug 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## CONTINUOUS RECORDING OF RESISTIVITY WITH TOWED ARRAYS FOR SYSTEMATIC MAPPING OF BURIED STRUCTURES AT SHALLOW DEPTHS

Michel DABAS\*, Jean-Paul DECRIAUD\*, Georges DUCOMET\*\*, Albert HESSE\*, Alain JOLIVET\*,  
Abdo MOUNIR\*\*\* et Alain TABBAGH\*\*\*\*

**Résumé:** Depuis les premiers essais de mesure des résistivités pour la prospection archéologique, la technologie a considérablement évolué. On est passé des électrodes déplacées à la main à des systèmes tractés avec contact continu sur le sol et enregistrement automatique des données. Les derniers perfectionnements portent sur les quadripôles électrostatiques qui ne nécessitent plus aucun contact électrique avec le sol. L'article rappelle la contribution du Centre de Recherches Géophysiques de Garchy à cette évolution au cours des trente dernières années.

**Abstract:** Since the first experiments of resistivity measurements for archaeological survey, technology has shown a considerable evolution. Electrodes moved by hand have been exchanged for towed arrays with continuous contact with the ground and automatic recording of data. The last improvements consist in the use of electrostatic quadrupoles which no more need any electrical contact with the ground. The paper recalls the contribution of the Centre de Recherches Géophysiques at Garchy in this evolution during the last thirty years.

**Mots-clés:** Géophysique, résistivités, prospection, archéologie.

**Key-words:** Geophysics, resistivity, survey, archaeology.

Inserting electrodes into the ground has long been a considerable limitation for the development of resistivity measurements in archaeology. Many improvements have been considered by us as well as by other scholars with more or less efficiency. They all intended to speed and to make easier probe insertion. Simultaneously, automatic data acquisition systems were developed so that large areas could be investigated at a faster rate, that is to say at a lower price.

An alternative solution could have come from electromagnetic devices and especially the Slingram configuration. They do present a considerable interest from a theoretical as well as from an experimental point of view since their most sophisticated versions can allow simultaneous measurements of electrical conductivities and of magnetic susceptibilities. Our laboratory has created the SH3 and we still are very much interested in its applications.

Despite this, direct measurements of resistivity with injection of current into the ground still offer a number of advantages among which are: a good response to resistant features, weak effects due to apparent anisotropy and near-by metallic disturbances and an invaluable ability to simultaneously investigate at different depths. These considerations explain our constant inter-

est in this method and our efforts for improving its efficiency by developing the continuous automatic recording of subsurface resistivities with towed arrays of electrodes.

This could not have been without systematic attention paid to the theoretical aspects of the problem (*i.e.* models calculations, automatic interpretations in three dimensions, comparison of the different electrode arrays abilities, signal processing, appropriate data mapping,...). This is another subject and we shall discuss only on the instrumental and experimental aspects of our research.

The first experiment was made in 1965 with four wheel electrodes, a manually balanced resistivity meter and a mechanical recording system which could only provide an analog drawing of the profiles: this almost «prehistorical» attempt took place at the site of Pincevent (Hesse, 1966).

The following prototype was achieved in 1981: it consisted in a square array with conductive jet electrodes, a Bradphys resistivity meter and a paper recorder. The system was operational but far too heavy, not very accurate, and the still analog recording was too much time consuming for maps producing (Hesse, Jolivet & Tabbagh, 1986). The Neuville-sur-Loire survey gave clear

\* Centre de Recherches Géophysiques, C.N.R.S., 58150 GARCHY, FRANCE.

\*\* C.R.G. et Ministère de la Culture.

\*\*\* C.R.G. et Géoméga S.A.R.L.

\*\*\*\* C.R.G. et Université de Paris VI.



MONTBARON (36) 1992

Prospection RATEAU. Resistivite apparente.

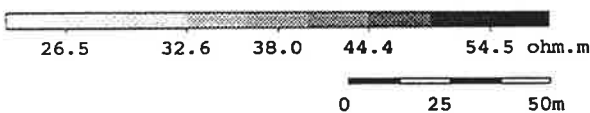


Fig. 1: Apparent resistivity; RATEAU survey on a medieval farm site at Montbaron, France.

indications for the position of the Roman buildings but could not reach the accuracy of the traditional «hand made» measurements.

Then a considerable improvement came with our new RMCA resistivity meter built by the C.N.R.S. and Septa S.A. in 1984 and continuously improved since then (Dabas, Hesse & Jolivet, 1990). It now includes a microprocessor and is associated, on the towing machine, with a computer which provides a fully versatile program of measurements sampling. A small velocity radar fixed to the machine correlates the measurements with the position on the ground. The graph of the profile is displayed on the screen and can be controlled in real time. The data are generally acquired at a 10 cm interval on the profile and the maps are subsequently processed after an appropriate filtering and a resampling at a 1 m interval in both directions. We call it the RATEAU system which is an acronym. Several surveys have been conducted with the prototype, on large surfaces or long profiles (Dabas, Hesse & Jolivet, 1989) (Ducomet & Hesse, to be published) and different systems of electrodes are now available.

The example of Balloy is of interest since it was largely excavated after the survey. Two large oval funery enclosures consisting of a back filled ditch could be seen on the map among strong anomalies produced by gravel or clay deposits: and were clearly correlated to the map of the excavated features. The last experiments consisted in several other large surveys in excess of 1 ha, with a small grid (1x1 m), at different archaeological sites such as Montbaron (fig. 1). The same kind of satisfactory results at shallow depths were obtained for civil engineering on a road way before the tarmac was spread: the limestone outcrops produce a strong contrast with finer deposits (fig. 2).

However we could not avoid a comparison with the technical option developed here in Great Britain by the Bradford school: that is to say the twin electrodes configuration and the very efficient instruments built by Geoscan. We have started and we still plan comparative surveys using both systems with the geophysical survey groups in England. The newest result we can present at the moment is an experimental light prototype (fig. 3) which combines the advantages of both techniques: the twin electrodes resistivities can be automatically recorded and the first experiments conducted with the internal clock of the microprocessor on a same profile show a very good repeatability of the anomalies given by an artificial wall and a natural fault which are the typical targets of our test field in Garchy (fig. 4).

Another direction of research concerned the use of non ground contacting electrodes, at frequencies in excess of 10 kHz, for the measurement of both resistivity and permittivity. The first experiments were conducted with a prototype bearing four dragged electrodes consisting in a pack of chains contained in a plastic bag. In the case of Favray we have been able to demonstrate that the so called «electrostatic resistivities» were in perfect accordance with the previous resistivity measurements, as given by the RATEAU, for the archaeological features (road and small building) as well as for the geological ones (Tabbagh, Hesse & Grard, 1993).

One of the main interests of this technique lies in its ability to provide measurements through pavements where electrodes cannot be inserted and several experiments have been conducted in churches: in the choir of Autun's cathedral, we had an opportunity to compare the survey with excavation and direct measurements of the resistivity of the exposed sediments with a small quadripole ( $a = 0.3$  m). The complexity of the structures, which is typical of such an archaeological context, was a limitation in the interpretation, but the orders of magnitude of resistivity revealed very satisfactory (Tabbagh, Hesse & Grard, 1993).

Another advantage of such a device comes from its ability to provide data concerning dielectric permittivity.

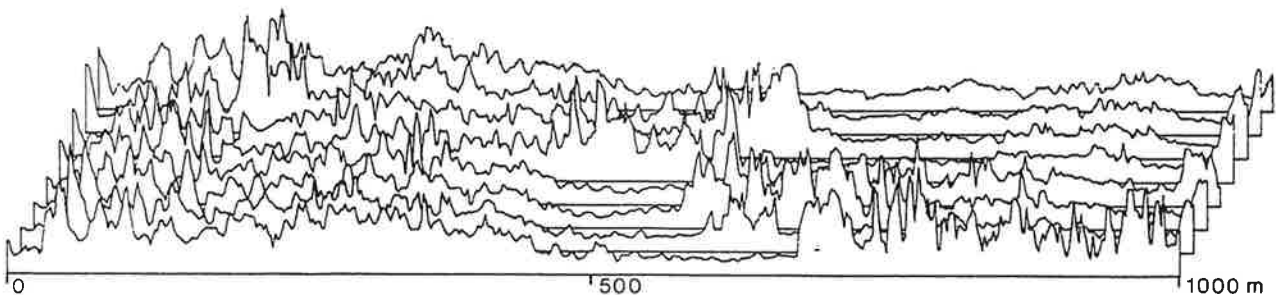


Fig. 2: Profile representation of continuous RATEAU recordings on a road way; high resistivities (around 250  $\Omega$ m) represent limestone of Vermenton outcrops contrasting with finer deposits (50  $\Omega$ m); interval between profiles = 2 m.



Fig. 3: Experimental prototype of a «twin electrodes» array for resistivity recording with the RATEAU acquisition system.

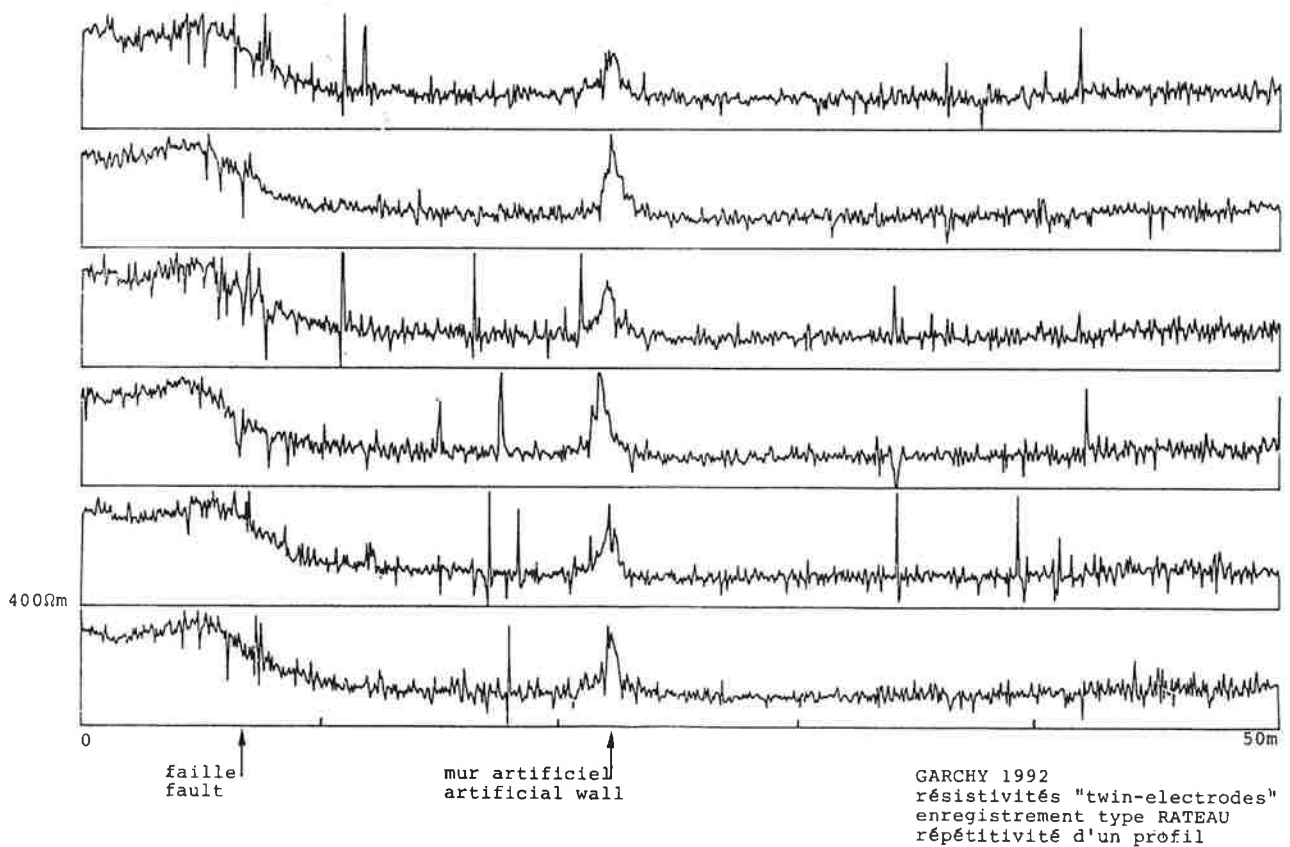


Fig. 4: Field trials of the recording «twin electrodes» array on typical shallow depth features at the Garchy test field.



Fig. 5: The new electrostatic quadrupole: the electrodes are contained in the wheels.

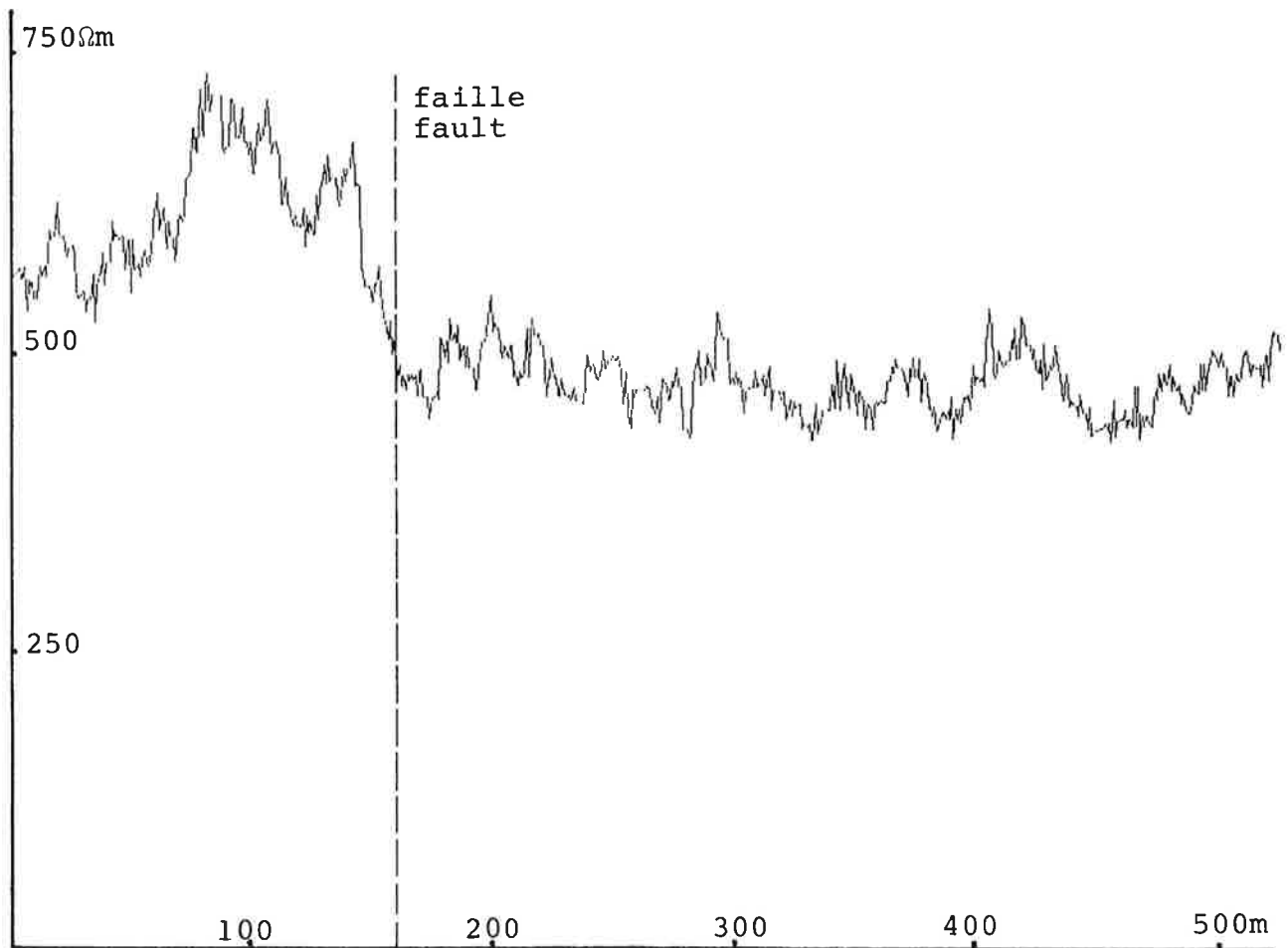


Fig. 6: A long high speed resistivity profile obtained with the electrostatic quadrupole on a road covered with tarmac.

At the moment we could obtain valid results on the high resistivity soils of Mont-Beuvray only (Tabbagh, Hesse & Grard, 1993). The value of this new information in archaeological surveying, in comparison with resistivity, still must be carefully investigated prior to any routine use.

Finally we now have at disposal a new prototype (fig. 5) which is still under experiment: our last results were obtained at relatively high speed (50 km/h) over a distance of several kilometers on a road covered with tarmac. The figure 6 shows a sample of the data over 500 m where short and long wave anomalies can easily be recognized together with the typical anomaly of a fault in the underlying limestone. We think that these results open rather wide prospects not only for archaeological surveying but also for other types of targets like those which are of interest in civil engineering, geotechnics, agronomy or environmental studies (Dabas *et al.*, 1989).

#### NOTE A L'INTENTION DU LECTEUR

Ce texte est celui d'une communication présentée oralement par A. Hesse à l'invitation du «British Geological Survey», au cours d'une journée «Archaeological Geophysics» organisée par «The Environmental and Industrial Geophysics Group of the Joint Association for Geophysics» à Londres, le 15 Décembre 1992. Initialement destiné aux Actes de cette journée qui n'ont finalement pas été rassemblés et publiés, il est ici présenté dans sa forme originale.

Le contenu du texte, qui vise à faire un bref historique des recherches sur les mesures de résistivité pour l'archéologie au Centre de Recherches Géophysiques de Garchy, recouvre par ailleurs en substance la présentation qui avait été faite au Colloque du G.M.P.C.A. au Mont-Beuvray (26-28 Avril 1993) sous le titre «Mesure automatique en déplacement continu de la résistivité électrique du sol. Bilan d'une trentaine d'années de recherches» au nom des mêmes auteurs avec l'adjonction de J. Gallego, Y. Spahos, J. Tabbagh et P. Trameson.

#### BIBLIOGRAPHIE

- DABAS, M., DUCOMET, G., HESSE, A., JOLIVET, A. et TABBAGH, A., 1989 - Intérêt de la cartographie de la résistivité électrique pour la connaissance du sol à grande échelle, *Science du sol*, 27 (1), 65-68.
- DABAS, M., HESSE, A. et JOLIVET, A., 1989 - Premiers résultats et perspectives pour l'exploration géophysique des sites métallurgiques médiévaux de Minot (Côte-d'Or), *Actes du 112ème Congrès national des Sociétés Savantes, Lyon 1987*, C.T.H.S., Paris, 129-144.
- DABAS, M., HESSE, A. et JOLIVET, A., 1990 - Prospection électrique de subsurface automatisée, *Aerial photography and geophysical prospection in archaeology, Second Interna. Symp., Bruxelles, C.I.R.A., 8 novembre 1986*, 73-82.
- DUCOMET, G. et HESSE, A., sous presse - Prospections géophysiques sur le Mont Beuvray, *Environnement et prospection*, publ. du Mont Beuvray.
- HESSE, A., 1966 - Perfectionnement des applications archéologiques de la prospection électrique, C.R.S.M., *Soc. préhist. française*, LXIII (1), XV-XIX.
- HESSE, A., JOLIVET, A. et TABBAGH, A., 1986 - New prospects in shallow depth electrical surveying for archaeological and pedological applications, *Geophysics*, 51 (3), mars, 585-594.
- TABBAGH, A., HESSE, A., et GRARD, R., 1993 - Determination of electrical properties of the ground at shallow depth with an electrostatic quadrupole: field trials on archaeological sites, *Geophysical Prospecting*, 41, 579-597.

