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Geophysical study to characterize input karst water circulation in the saulges cave (Mayenne, France)

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Key words: Karst, Geophysics, Saulges, Margot, Geology.

INTRODUCTION

The landscape around the Saulges caves is a limestone plateau cut by the valley of the river Erve. Some of the caves in the sides of this valley contain prehistoric art (Pigeaud, 2004; Pigeaud *et al.*, 2006) and should therefore be protected from water trickling down the walls. This study is part of a program: “Occupations paléolithiques de la vallée de l’Erve” conducted by UMR 6566 for CNRS “CReAAH”, coordinated by Jean-Laurent Monnier.

Geophysics could be useful in finding new caves and detecting preferential pathways (Al Fares *et al.*, 2002; Guérin and Benderitter, 1995; Guérin *et al.*, 2008). A frequency-domain electromagnetism instrument at low induction number (EM31) was used to map the site and to detect geological anomalies. Electrical Resistivity Tomography (ERT) gave details on a small number of anomalies.

GEOPHYSICAL METHODOLOGY

The EM31 equipment is a simple “slingram” (McNeill, 1980; Frischknecht *et al.*, 1991) consisting of a magnetic

dipole (a current loop) transmitter (T_x) and a coplanar magnetic dipole receiver (R_x) operating at a fixed frequency of 9.8 kHz. This instrument is used to map average variations of electrical conductivity at depths between 0 and 5.5 m in the DMV (Dipole Magnetic Vertical) configuration. In fact, in DMV configuration, the axes of the two magnetic loops are vertical and the sensors are more sensitive to average conductivity around 1.8 m below the surface.

The ERT system (Dahlin, 2001) is a multi-electrode resistivity-meter. It consists of an electrode array, control unit, data acquisition and processing unit, image reconstruction and analysis unit. The sensor of the ERT system is an electrode array with 72 metal electrodes locating equidistantly along a profile. The exciting current is injected between two electrodes order by order, and two other electrodes measure the electrical potential difference. An ERT helps determine horizontal and vertical electrical resistivity contrasts, and thus is able to provide geological information, like the level of fracturing. Different arrays and spacing have been carried out: Wenner-Schlumberger and dipole-dipole with inter-electrode distance of 2 m and 3 m. The Wenner-Schlumberger array is recommended to detect horizontal and vertical structures, whereas the dipole-dipole is more

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sensitive to vertical structures and has a bigger investigation depth, but a lower signal-to-noise ratio. Afterwards, the RES2DINV program uses the smoothness-constrained least-squares method inversion technique to produce a 2D model of the subsurface from the apparent resistivity data (Loke and Barker, 1996). So, a 2D model of resistivity is calculated to explain measures as best as possible and the criterion used to evaluate the model is the RMS (Roots Mean Square), difference between measured and calculated data.

Therefore, the aim of the survey is to detect karstic features, like sinkholes or fractured zones which could communicate with the underground network. New caves or extensions of known galleries are expected, too.

RESULTS

The apparent conductivity maps (Fig. 1 and 2) were obtained using EM31 combined with a GPS.

In the case of the plateau (Fig. 1), a conductive anomaly appears at the bottom center of the EF section, corresponding to a circular anomaly (letter M, 12 mS/m vs. 5 mS/m in the neighborhood) on the EM31 map. These measurements are evidence for a big overburden. It seems to communicate with the underground network, because of

the vertical anomaly in the section at coordinate $x=62$ m. However, the latter could be an artifact of the inversion processing, so this vertical structure should be interpreted with caution. Another conductive zone is observed to the left of the section, at a depth between 10 and 20 m; it seems to be in relation with a large rectangular anomaly (letter N) on the conductivity map. Further investigations are needed to confirm and interpret these structures.

In the case of the valley (Fig. 2), the middle of the CD section presents an important discontinuity in the resistivity (100 vs. 3000 Ω m) and corresponds to a light anomaly on the EM31 map. Perhaps it is a cavity (full of water or sediments) on an unknown level of the karstic network, because there is evidence of vertical connections in neighboring caves (an inferior collector, under the Erve River level, was predicted by a karst study, Rodet *et al.*, 2001). RMS values are higher than in the case of the plateau, because the dipole-dipole array has a lower signal-to-noise ratio than the Wenner-Schlumberger array.

The AB section (Fig. 2) shows a conductive zone on the right side (coordinate $x=155$ m) and results from the EM31 show that the profile is not set in the center of the anomaly (letter P, 15 mS/m). The results may both correspond to an old river meander.

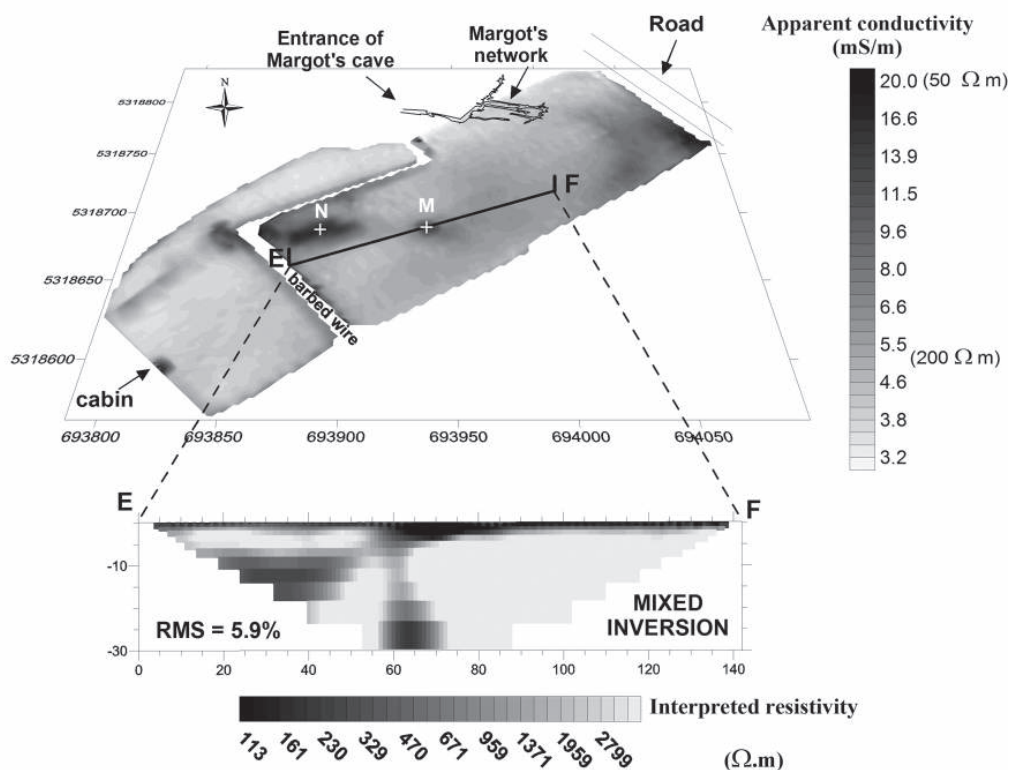


Figure 1: Section of resistivity and EM31 maps on the plateau (with a data grid around 5 m x 1 m). The section is a combined inversion of the Wenner-Schlumberger and dipole-dipole arrays. A map of the known underground network was plotted (around 15 m below the surface).

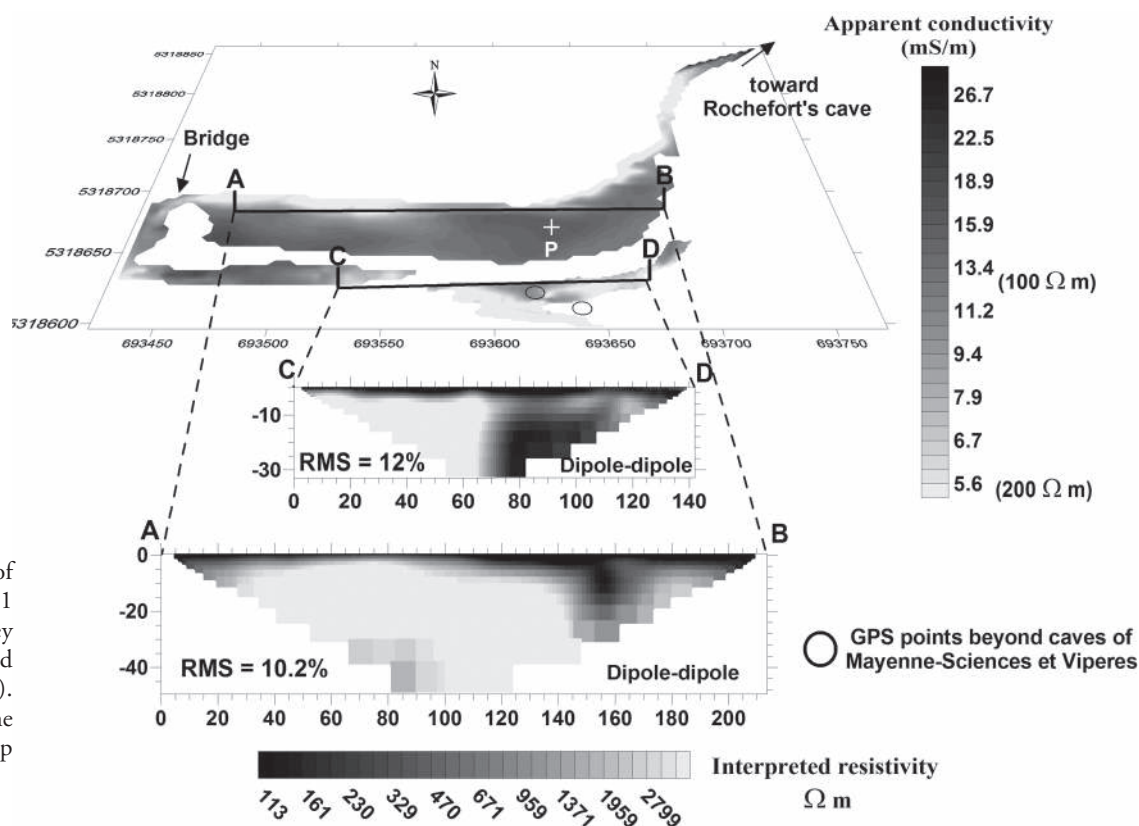


Figure 2: Sections of resistivity and EM31 maps in the valley (with a data grid around 5 m x 1 m). The river flows at the center of the map from east to west.

CONCLUSION

Some karstic structures may have been detected, but more geophysical investigations and excavation are needed to confirm these results. The survey zone has to be extended to detect other anomalies and a possible preferential direction of the fractured rocks. Connections between superficial structures and cavities have to be performed, too.

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