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Seismic and geomagnetic survey in an archaeological site at Chartres, France - evidences of paleo-channel and remains of a Roman temple

A. Fernández Visentini* (Institut de Physique du Globe de Paris), K.-Y. Ke (Institut de Physique du Globe de Paris), J. Lartey (Institut de Physique du Globe de Paris), V. Abhishikth (Institut de Physique du Globe de Paris), C. Delahaye (Institut de Physi

Summary

Seismic and geomagnetic studies are conducted in an archeological site around the Bas Bourgs Municipal Stadiums of Chartres, France. The tomographic velocity model obtained from active seismic data reveals traces of an inferred initial location of river beds of the Eure river ~50.0 m away from its current location. Excellent agreement between results from the magnetic survey and previous studies indicate new evidence for the presence of an antique Roman road and remains of a Roman sanctuary beneath the nearby football field.

Introduction:

The historic city of Chartres is located 90 km away from Paris in southwest direction. The famous cathedral of the city is one of the historic remains that attracts visitors from all over the world and it is no exception that the Government of France has established the Archaeological Department of Chartres to investigate the area. In 2006, remains of a Gallo-Roman temple were discovered around the Church of Saint-Martin-au-Val. Since then, the Archaeological Department of Chartres has been conducting many surveys in collaboration with geophysical institutions in France. One outcome from these studies has been the discovery of an antique Roman road in the area of the Bas Bourgs Municipal Stadiums which was revealed during excavations. According to the results obtained from a Ground Penetrating Radar (GPR) survey conducted in 2015, the road is expected to continue below the adjacent football field (see Figure 1). At the same time, archaeological investigations suggest that the Eure river in Chartres might have shifted from a different position to its current location over the years and that the former river path should be found somewhere below the main field of the aforementioned stadiums.

The discoveries mentioned above have led us to select this area to conduct seismic and magnetic surveys in collaboration with the Archaeological Department of Chartres as part of the 2016-17 GPX Master program of the Institut de Physique du Globe de Paris (IPGP). We conducted a seismic survey to locate the old path of the Eure river and several magnetic surveys to complement previous GPR results regarding the remains of the Roman road and temple. The magnetic survey showed a very good agreement with previous GPR data, supporting the idea of the continuation of the Roman road beneath one of the fields and also the presence of remains of the temple. From the results of the seismic survey we argue that, indeed, the old river path is to be found beneath the main field of the stadiums.

Methodology

Seismic survey: As mentioned, the ancient path of the Eure river was expected to be somewhere below the main field of the municipal stadiums. We deployed a 180 m seismic line along which 24 vertical component channels spaced by 5 m were moved two times to cover its full length across this field. A sledge hammer was used as an impulsive source at the midpoint between each pair of receivers and five consecutive hits were made at each source position and then stacked. The travel times corresponding to the first P-wave arrivals were picked in seismic picking software Pickwin and were used as the input for Plotrefa software implementation of first arrival tomography (Zhu et al. (2008); Taillandier et al. (2009)). For the initial velocity model we estimated a maximum velocity of 3km/s and a minimum velocity of 0.3 km/s.

Magnetic survey: The magnetic survey consists of recording the magnetic field magnitude in five patches using a gradiometer with a sampling rate of 0.1 s along parallel lines spaced by 1m to cover the survey area as shown in Figure 1a.To avoid perturbations, we did not collect the data around 10 m of the goal posts. The Geometrics G-858 is a cesium magnetometer comprising two vertical-aligned and 1 m-separated sensors that independently record the magnetic field magnitude with a resolution of 0.01 nT and a noise sensitivity of 0.008 nT/Hz-RMS. As the magnetic intensity varied broadly for some patches (up to 10000 nT), we calculated the median M and standard deviation to consider readings only within one sigma of the median. The data were input into a Matlab implementation modified from Young (2004) which interpolates linearly the grid data points in order to render the corresponding plots.

Results and Discussion

Figure 1b shows the velocity model from the seismic survey. At shallow depths, the general tendency is a velocity increasing from right to left. For the right side of the seismic line, velocities do not reach values above 1500 m/s, while for the left side the maximum value is approximately 2500 m/s. In addition to this general theme, we also observe lateral anomalies on the right end. Approximately between 30 and 70 m a considerable decrease in seismic velocity is observed. For depths of approximately 12 m at the center of the depression, an anomaly of -800 m/s is observed with respect to the adjacent parts at the same depth. We consider that this smooth decrease is occurring due to the presence of uncompacted

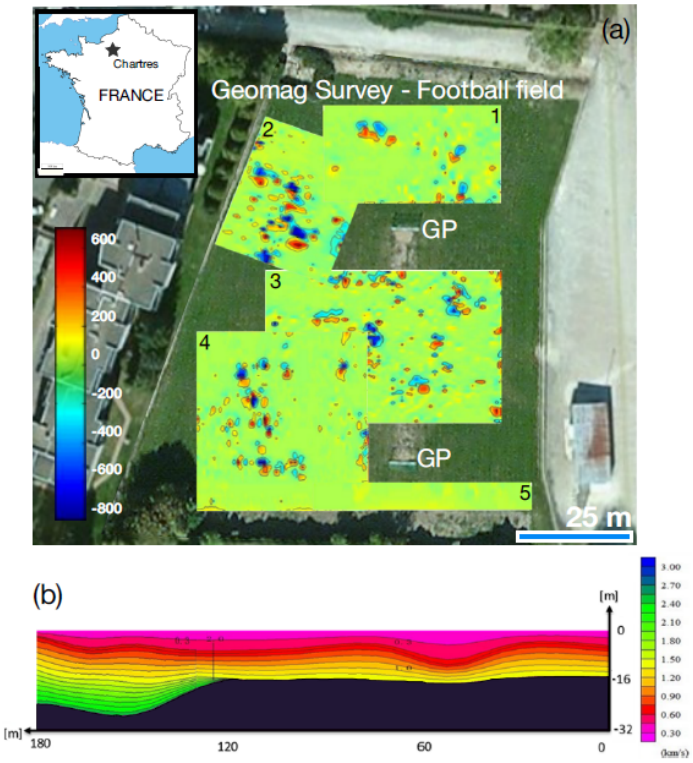


Figure 1 *(a) Adjacent football field. Plot of the magnetic field gradient recorded in five patches. The color scale is in nT. GP denotes the goal posts. At the top left corner, the location of Chartres in France is shown.(b) Velocity model obtained from First arrival Tomography using the seismic survey.*

sediments of the old path of the river Eure. In Figure 1a, we have the variation of vertical gradient of magnetic field intensity over five patches. In patch number 2, two linear features of negative anomalies can be noticed, which are parallel and perpendicular to the seismic line and form an inverted L-shape. This must probably correspond to one of the corners of the Gallo-Roman temple. Another notable feature can be observed in patch number 3. Here, again, a square shape is formed by lines of roughly negative anomalies. Additionally, in a very good agreement with previous GPR results, our data shows two parallel linear features in patch number 3, suggesting the path of the ancient Roman road.

Conclusions:

We conducted seismic and magnetic near surface surveys to image the shallow subsurface over the area of the Bas Bourgs Municipal Stadiums of Chartres. From our interpretation of the results we obtained, we make the two following conclusions: The magnetic gradient anomalies we observed, indicate the presence of remains of a human-made structure and are in excellent agreement with GPR data previously acquired. These results remain to be validated in the future studies and excavations by the Archaeological Department of Chartres. Regarding the seismic survey, using travel time tomography we were able to image a low velocity anomaly whose magnitude and shape suggests the presence of an old riverbed.

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