# New archaeological discoveries through magnetic gradiometry: The early Celtic settlement on Mont Lassois, France

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The burial complex of the "Lady of Vix" was discovered and excavated in the 1950s at the foot of Mont Lassois (Figure 1), a mountain situated close to the town of Chatillion-sur-Seine in the Bourgogne region of France. The assemblage of the burial goods was rather extraordinary, including such items as an artfully crafted golden necklace with winged horses and a voluminous wine-mixing vessel, probably made in a Greek workshop, capable of holding 1100 liters. According to archaeological research, this member of the aristocracy must have lived during the period between 550 and 500 BCE. Several large-scale geophysical research projects were undertaken in the vicinity of the burial complex during the last few years to learn the history of the settlements from that period. This led not only to the discovery of the expected settlement structures, but also to the discoveries of the remains of several large burial mounds that had been erected along the River Seine.

***Figure 1.*** *Aerial photograph of Mont Lassois, view from east toward the plateau (Photo courtesy of Rene Goguey).*

Yet one question still remained unanswered: Where were the lady's residential and representational buildings? The traces of two ditch structures aligned in a T-shape were subsequently recorded during two small scale geomagnetic surveys on the nearby plateau of Mont Lassois. In the following summer campaigns of 2003 and 2004, the entire plateau of the mountain underwent a geomagnetic survey, and additional areas were investigated with the use of ground radar. This led to the discovery of an unusual Celtic building.

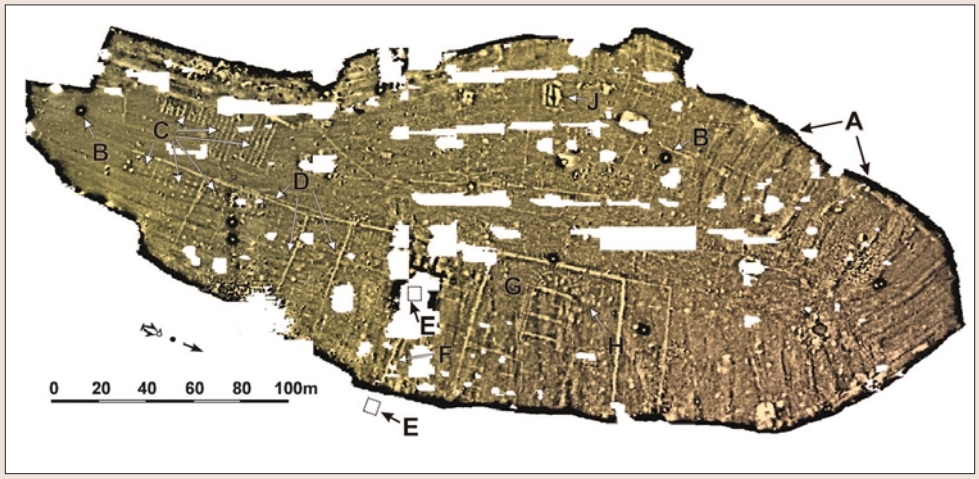


***Figure 2.*** *Magnetic vertical gradient map of the plateau of Mont Lassois. Dynamics: -6 nT (black) / +7 nT (white).*

**Survey design.** Due to the dense foliage, access to the plateau was in parts rather difficult. A 20×30-m survey grid was erected on the plateau with the help of a differential GPS system and then subdivided into 5×20-m partial grids. Because most archaeological anomalies hardly achieve a value of more than 10 nanotesla (nT), the sample-interval and the traverse-interval were set at 0.25 m to record small anomalies at a high resolution. Thus, in every one of the 5×20-m grids, some 1600 measurements were carried out. The survey was performed with a fluxgate-gradiometer manufactured by Geoscan Research. This handheld instrument measures the vertical gradient of the earth's magnetic field with two sensors (resolution of the sensors: 0.05 nT). Only the white areas seen on the magnetic map had to be left out due to dense undergrowth. In the summer campaign of 2003 temperatures of up to 143.6° F were measured in sunny areas on the sites of the archaeological excavations on the mountain. Surprisingly, the survey with the fluxgate-gradiometer could be carried out without problems even under these extreme conditions. Only the pitch of the built-in metronome, which ensures a constant survey speed, changed constantly—or sometimes failed completely.

**Discoveries by magnetic imaging.** The plateau of the mountain is surrounded by a fence. The magnetic anomalies (vertical gradient) originating from this fence are shown in the magnetic map (Figure 2) as a black edge, marked with the letter A. Since the mountain was surveyed topographically,

several boundary markers with iron cores were employed which can be recognized as black, circular structures with a white center (B). Besides these two features one can also recognize anomalies characteristic for certain archaeological structures in the magnetic map. Some 2500 years ago, large granaries and public buildings, recognized as such in the results of the excavations of 2004, stood in the southern part of the plateau. Their postholes in which the wooden roof-supporting posts were set are clearly recognizable as a dotted line (C). The eastern part of the plateau was subdivided by palisades (D) into separate areas, perhaps for housing and mews, of which the true meaning yet remains unclear. Two cisterns with a depth and diameter of several meters can be recognized at (E) (one of the cisterns lies outside of the surveyed area). According to the magnetic map, the two cisterns were interconnected by a canal (F).

***Figure 3.*** *Sections of the apse of the building of yet unknown function, photographed during an excavation. The threefold concentric row of postholes can clearly be recognized, their positions marked by white pegs.*

The discovery of these individual structures in an early Celtic hilltop settlement through magnetic gradiometry is so far without precedent. Especially the building (G) is regarded as spectacular by the archaeologists. An apse can be recognized in the west, possibly consisting of a threefold concentric row of posts—if one of these rows of posts is not from an earlier construction period (Figure 3). Two large rooms were adjoined to the east. The particular alignment of eight posts (H) in the northwestern area of the building allows us to presume that this is where the entrance hall was situated.

In addition, trenches from a 1960s excavation can be recognized in the magnetic field (J).

**Conditions.** The excavations that started in 2004 have shown that the cover of topsoil on the plateau is rarely thicker than 30 cm, mostly reaching a thickness of just 20 cm. Following this A-horizon is a C-horizon consisting of nonmagnetic limestone (the B-horizon is missing completely). The success of these geomagnetic surveys on Mont Lassois is due entirely to the existence of the magnetic topsoil of the A-horizon. The various amounts of magnetic anomalies, recognizable as variations in brightness within the magnetic map, have their origin in the different degrees of infill of the postholes and ditches with this soil. Because of these observations, the following experiment was conducted.

**Improved survey design.** The building designated (G) is the focus of archaeological research from 2004 to 2006. Trees had to be felled, bushes cleared and the topmost layer—some 10 centimeters—of soil had to be removed prior to the beginning of the excavations in July 2004. After this was completed the intended area of the excavation was once more surveyed with the fluxgate-gradiometer, this time with a traverse- and sample-interval of 0.125 m. The magnetic contrasts become considerably clearer when we compare the results of this survey with the corresponding segment of the magnetic vertical gradient map of the plateau (Figure 4). The use of gradiometry is preferable so that we can reduce or cancel the effects of background noise and of metallic objects near the area of investigation. Nonarchaeological structures close to the surface are not found any more in the second survey. Additionally, the contrast of the magnetic anomalies of the archaeological structures was significantly improved. The reason for this effect cannot be found in the chosen denser survey grid alone. The lack of the topmost soil layer, which obviously has a filtering effect, has an influence on the quality of the recorded geomagnetic anomalies which should not be underestimated. Single rows of postholes (K) can therefore now be recognized that were previously indefinable in the magnetic vertical gradient map of the first survey and were only apparent as a ditch structure. Moreover, the anomalies marked (L) can now be addressed more surely as an additional possible small tem-

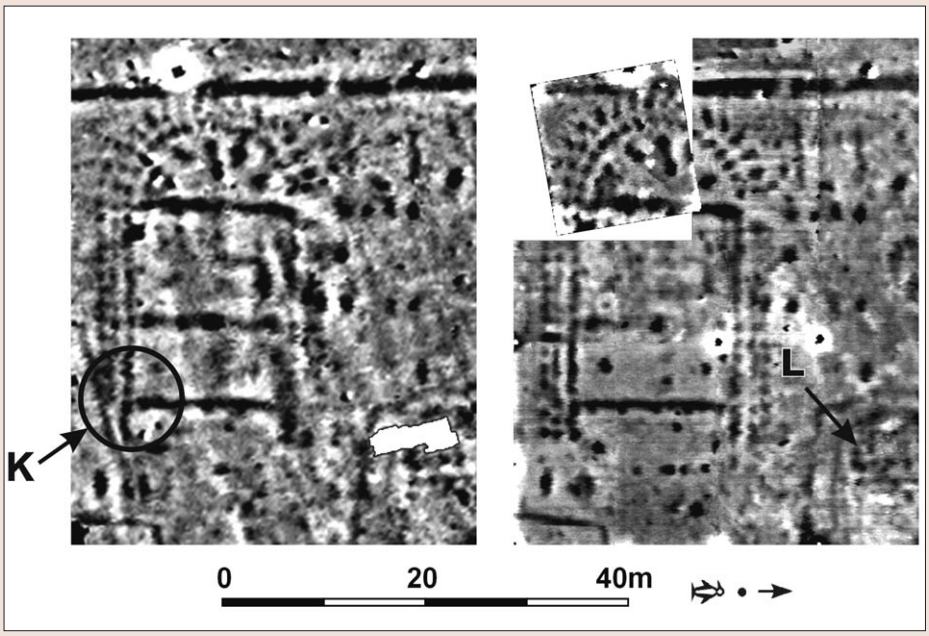


***Figure 4.*** *(Left) Section of the magnetic vertical gradient map with 0.25 m resolution. (Right) Result of the geomagnetic vertical gradient survey after removal of 10 cm of topsoil and a resolution of 0.125 m. The gray scale is inverted; white areas were not surveyed. Dynamics: -4.5 nT (white) / +5 nT (black).*

ple-like outbuilding (with an apse and linear-aligned postholes). Strong magnetic anomalies recognizable in Figure 4, but not in Figure 2, were caused by nails marking the site of the excavation. The geophysical survey was aligned along the excavation grids which had two different orientations in 2004 and 2005. The small, slightly veered partial area in Figure 4 was surveyed in 2004, the large contiguous area in 2005.

**Conclusions.** The excavations carried out on the mountain have confirmed the results of the geophysical survey in all detail. The geomagnetic measurements that were repeated after the removal of the topmost layer of soil showed that even such a layer of just 10-cm thickness can act as a significant muffling filter to the geomagnetic anomalies. The geomagnetic survey with a very tight sample- and traverse-interval of just 0.125 m proved to be helpful in specifically addressing the anomalies and in preparing for the excavations. Even if such a tight survey is more time-consuming than a "normal" survey, it should be considered for features that are to remain unexcavated in the ground.

**Suggested reading.** "Aperçus sur les fouilles reçentes du complexe aristocratique de Vix/le Mont Lassois" by Chaume et al. (*Bulletin de la société archéologique et historique du Châtillonnais, 6ème série*, 2004). TLE

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