Preventive Archaeology in France and the contribution of extensive geophysics: from ARP® to web-GIS

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PREVENTIVE ARCHAEOLOGY IN FRANCE

It is of common practice to say that land development is a significant threat to our cultural heritage. Even if this heritage is protected thanks to different laws in constant evolution, but also framed at a European level by various conventions, a mass destruction of this heritage was and is still on-going, more specifically for the part which is buried below the Earth surface. Only recently, thousands of sites have been systematically excavated before their complete destructions and this inflation of scientific data derived from their study (compared to the more traditional excavations done by researchers) has completely changed our view of the past. If we focus only for France, the total area impacted by development works is of the order of 60 000ha per year. This represents 165 ha per day or 7ha by hour! Among these 7 ha/hour, only about 1,5 ha is checked by archaeologists (evaluation trenches with mechanical stripping). Even if the ratio of evaluated areas seems low (circa 15%), over one year (2012), this represents an area of 15000ha and indeed a unique opportunity for archaeologists. These figures are now lowering due to the impact of the economical situation. It is important to note that in France the cost of archaeological evaluation/excavation is supported at 100% by the developer.

Rescue Archaeology has grown up in Europe due to the awareness of the value of buried heritage first by some amateurs, but also by the public and specifically into the historical districts of the towns. In France and in other countries like England, Ireland, Italy, scandals due to the voluntary destruction of archaeological remains is at the origin of the development of specific regulations and entities in Archaeology. Generally, this period is coincident with first, the post-reconstructions of big town centers throughout Europe, and then with the development of big infrastructures like motorways (France, Hungry, Ireland) and railways lines during the economical expansion (TGV in France). It is significant to note that the term ‘*Archéologie de sauvetage’* (Salvage Archaeology) first given to this type of Archaeology in

France, has evolved to '*Archéologie préventive'* (Preventive Archaeology) which is accepted nowadays (we will refer to it as PA later in this text).

In France, the 'case of Rodez' in 1993 – deliberate destruction of a roman site with a town in the South of France-, was the trigger for the reform of legal texts in Archaeology which resulted in the law of 2001. Before this law, the State relied on AFAN (*Association pour les Fouilles Archéologiques Nationales*) which was the main and nearly only institution in the archaeological landscape thanks to its major role in the excavation of "Grand Louvre" in the 80's. But it was not until the 90's that big excavations outside the main cities focused the interest of archaeologists: the factory of Toyota (Onnaing); ActiParc (Arras) or Airports like the one of Metz or Reims. In 2001, AFAN is dissolved and INRAP (*Institut National de Recherche en Archéologie Préventive*) is created directly under the Control of the State together with the regulatory texts (*Titre 2 Livre V du Code du Patrimoine*). For the first time the rules for funding archaeological evaluations are described and corresponds to a fixed price (5400€/ha in 2014). INRAP is defined as the only operator in PA. This law defines the status of Archaeological Heritage (Art. L. 510-1), and recalls that PA is a public service mission and is governed by the applicable principles of any scientific research. It clearly indicates that the objective is to safeguard our archaeological heritage when threatened by public or private constructions. State has to ensure "the reconciliation of the respective requirements of scientific research, conservation of our heritage and economic and social development". In this context, it is responsible i) for assessing the impact of the construction on the archaeological remains, ii) for prescribing the appropriate preventive archeology measures iii) for allowing field operations and designate the scientist in charge and finally iv) for exercising scientific and technical control over all of the operating chain (Art. L. 522-1). This mission is carried out in each of the regions (22) by the archaeologists of DRAC/SRA (*Direction Régionales des Affaires Culturelles/Service Régional de l'Archéologie*), and they can rely on expertise made by scientific advisory bodies such as the National Research Council for Archaeology (CNRA) and the 7 Interregional Commissions of Archaeological Research (CIRA). The state is also responsible for the preparation and updating of the Archaeological National Map (Art. L. 522-5).

The construction of PA in France was characterized by the choice to give the mission of management of our Cultural Heritage to the Ministry of Culture. This choice was probably dictated by an old tradition of "Heritage Management", initiated for example by Prosper Mérimée in the XIX th century, but this was not accounting for the *primogenitus* competence of the two other Ministries (Research and Education) in the field of humanities research.

Universities (Ministry of Education) and CNRS (Ministry of Research) were fifteen years ago the pillars of research in the field of national archaeology. But neither of these two entities was awarded a real leadership in the field of Rescue Archaeology, now referred as PA. INRAP plays now *de facto* a monopoly which tends to override any other research done by researchers in Universities or in CNRS. (F. Djindjian, L. Orengo, pers. com.).

In 2003, a new law opened archaeological excavations to market competition. But archaeological evaluations, since they are the basis for the prescriptions of State archaeologists (*DRAC/SRA*), are not open to private competition. Beside INRAP, this law also opened to local authorities (*CT :Collectivités Territoriales*) the possibility to undertake evaluations in their own region. State control is strong: private companies and local authorities have to apply for an agreement in order to work in Archaeology (INRAP is the only exception), evaluation and excavation reports must be appraised. This opening has resulted in the creation of 67 entities for archaeological evaluation and 81 for archaeological excavations (2012). It is estimated (2012) that the number of archaeologists in PA in France is 3142 of which 62% are in INRAP, 23% in CT and 15% in private companies. Considering a number of 25000 archaeologists in Europe, this represents 12% of this population.

Last year (2013), a white paper ("*Livre blanc"*) was delivered by the Commission designated by the Ministry of Culture. The mission was to conduct an assessment of the situation of PA ten years after, to evaluate the place of PA in the archaeological French community and to propose a new project for PA, and where appropriate, integrate into the draft law to be presented to Parliament. The new regulations are coming soon (2015) but it is too early to discuss them in this paper. We can only summarize here the situation in 2014.

State services receive an average of 35000 projects per year. These projects can be divided in four categories: all works which are submitted to impact assessment (railways, roads, motorways, quarries); ZAC (Concerted Development Areas) or allotments of more than 3ha, works on buildings classified as Historical Monuments and works submitted to declaration or authorization under the Code of Urbanism. Depending on the state of archaeological knowledge in the region and to the degree of destruction linked to the type of work, the '*Préfet*' (local representative of the State in each region –*département*- and also the local representative of the Ministry of Culture) can ask for i) an assessment through an archaeological evaluation, ii) conduct excavation or, iii) modify the consistency of the project in order to preserve the archaeological remains. Among the 35000 projects, 2500 will go through the archaeological evaluation process (7%). Even if there is no evaluation, all planners have to pay a fixed tax for archaeology (RAP, 5400€/ha). When the final report is emitted, the *Préfet* can ask for archaeological excavation (550 cases= 20% of evaluated surface=1,5% of all projects). In this case, the price of excavations is subject to competition (ten thousands to several hundred thousands of €/ha). Beside excavation, two other possibilities exist: first, there may be changes in the project, in order for example to avoid the destruction of the most valuable artifacts by changing the dimensions and the positioning of the project. Second, project can also be abandoned generally due to the price of excavations compared to the economical value of the project. It is observed that reluctance of developers to Archaeology in France is the result of: i) delays and destruction of land by the mechanical trenches during evaluation process, ii) delays and price of archaeological excavations, iii) difficulty to forecast the archaeological risk.

During evaluation, the only process accepted by the French archaeological community is systematic mechanical trenching with a regular mesh (*sondage systématique à la pelle mécanique avec une maille régulière*) at 10% minimum of the surface. This process developed during the 80's in Lorraine region was systematically applied since the 90's and is now considered exclusively to any other techniques. From the mechanical point of view (geotechnical engineering), the mixing of earth and the mechanical destructuration of the soil layers is a drawback for the construction project. From the communication point of view, these trenches, most of the time not refilled until the beginning of constructions, sometimes several years after, is not the best 'image' to show to the public. Also these trenches prevent using the fields for agricultural purposes during the time between evaluation and construction. Finally, from the scientific point of view, a regular mesh may not the best strategy to discover sites as opposed to oriented mesh (Marmet et al., 2002), the 10% of opening can be questioned (Blouet, 1994), and finally any new additional information should be considered to increase the predictability of detection of sites.

We should stress that the economical situation and the opening of Archaeology to private companies have now generated or enhanced some tensions. As the competition between companies is getting harder and harder, prices are getting down (a scenario known in England). Competition also between the public company (INRAP) and private companies or CT has resulted in a dumping of prices and services in Archaeology. Especially the quality of the evaluation reports, which are the base for the prescription of SRA for any further excavation, can be questioned nowadays for some of the actors in Archaeology.

HISTORY OF GEOPHYSICAL INVESTIGATIONS FOR PA IN FRANCE

As quoted before, the role of geophysical investigations in France in PA is null, as opposed to its systematic use in other countries like England, Netherlands or Hungry for example. Nevertheless, positive experiences have been undertaken since 1995 on motorways, Concerted Development areas and pipeline corridors.

One of the reasons which was advanced by field archaeologists not to use geophysics was the size of the projects involved in PA: indeed, it was not possible in the 90's to survey hundred of hectares or kilometers with the resolution needed for cartography of archaeological sites (1 square meter mesh at minimum). Consequently, the first trials were not designed for a precise cartography but only for detection of sites (absence/presence) or at maximum for the definition of sites boundaries. The first trial made was contracted to Terra Nova sarl. by SAPRR (*Société des Autoroutes Paris-Rhin Rhône*) over the A77 motorway in 1995. Roman heap slags were known to exist in a wooded area. The cartography of volume Magnetic Susceptibility (MS) was done by hand in the forest over an area of 300m wide and 1050m long with an electro-magnetic device (Geonics EM15) and a wide mesh (profiles in two directions parallel and perpendicular to the motorway main axis, 10m spacing along profiles). For the first time, it was possible to map the extent of 4 sites and this study also concentrated over the use of geostatistics (kriging) in order to recover the exact shape of the anomalies with a scarce geophysical sampling mesh (Figure 1). In this case, it was demonstrated that the mesh could have been lowered to 20mx50m and only in one direction (Dabas, 1999a). The success of this first trial has led to three consequences: i) the orientation of the motorway project was changed in order to avoid part of the sites, ii) a second study was ordered over a more important part of the motorway (A77South), iii) EM cartography was extended later to other motorways (A89, A20 and A66) and was the subject of a PhD thesis (Marmet, 2000).

The A77south was surveyed in 1995 over an extent of 100m wide and 15km long. One of the originality of the project was to use for the time GIS technology (GRASS and IDRISI) in order to gather all the available information and follow the process of data acquisition and interpretation (Chazaly and Dabas, 1997; Dabas 1999b). For the first time, MS mapping was used all over the project (MS2b Bartington, mesh of 10 x 25m) associated with local resistivity and magnetic surveys when high amplitude MS areas were discovered. The two GIS were used to combine existing maps (Aerial photos, Digital Elevation Models, Napoleonian Cadastre, a specific photogrammetric mission, *a priori* information coming from the National Archaeological Data Base) and also maps produced by our measurements (surface collection maps, a soil map and all geophysical maps). For the first time, it was possible to infer from a model, the possibility of erosion/accumulation of archaeological sites all over the project. After this survey, the number of potential sites has increased to 21 (only 2 were known before). Evaluation by mechanical trenches in a second phase was undertaken and sites were confirmed. MS mapping with other instruments (Geonics EM38) was then practiced with the work of E. Marmet for portions of different other motorways (A89, A20 and A66). The basic assumption of an enhancement of MS corresponding only to potential sites was proven too simple. Marmet main contribution was to confirm that site detection was indeed possible with large mesh mapping of MS, even for small sites, but sources of natural enhancement also exist and their contribution should be taken into consideration: over the 9 sites which were found by mechanical trenches, 7 were detected by their MS enhancement. All the other high amplitude anomalies were not interpreted as potential sites (false positive) because of specific soil conditions. For the 2 sites not discovered by MS, the author notes that "these 2 sites were first discovered by field walking and the possibility to discover them by mechanical trenches was very low". It is clear that detection of sites need the association of several technologies together like in the example of A77Sud.

In conclusion, MS measurements are a valuable tool for the discovery of archaeological sites but several drawbacks prevent to use them systematically: the instruments in the 90s were too slow to obtain measurement when small mesh measurements (1x1m) is desired over large surface, a deep knowledge of pedological factors has to be acquired in order to discard the false positive anomalies. Finally, the depth of investigation of these instruments is very low (several decimeters).

For these reasons, GEOCARTA has worked since 2001 on developing technologies able to capture mass data in the field efficiently (next paragraph) using both electrical, magnetic or EM fields. The first survey conducted in PA was over a 50ha field (ZAC of Vemars, GSE-Prologis) near Paris. Survey of the whole area was performed within only two weeks in 2006 and with a spatial resolution of 0,5m x 0,5m with three techniques (Figure 2). Only one archaeological site was discovered. Systematic mechanical trenching was done and this only site was confirmed (evaluation made by SDAVO). Unfortunately a second 'site' (a void protected by an arch) was discovered and destroyed during the leveling before construction because it was not detected during the mechanical tenching. Later analysis has shown that there was an anomaly associated to it but it was not interpreted. During the last 8 years, we have worked on more than 10 important projects (>20ha), most of them being Concerted

Development Areas (ZAC) or linear works (motorways, road deviation and pipelines corridors). At mimimum, resistivity and magnetic was used for detection of archaeological sites and, as soon as questions related to deeper layers (>2m) arose, EM was also considered. The biggest project was done in Italy for the BREBEMI consortium (motorway Bergamo-Brescia-Milano) and is explained earlier in this section of the book by S. Campana (Campana and Dabas, 2011). We will finish by the example of RTE Pertain. This work was contracted by RTE (*Réseau de Transport d'Electricité*) for the burying of a high voltage cable along a corridor 22km long. Archaeological research was not the main question in this research, but the occurrence of voids linked to remains of battle fields of the First World War in an area of the Western Front where the entrenchment of the Allied and German Front Lines began in the winter 1914-1915. As the impacted area of RTE project was less than one meter wide, the state services of Ministry of Culture did not ask for any archaeological evaluation by mechanical trenches. Nevertheless and in accordance with them and RTE, it was decided to survey with a very fine mesh (0,5 x 0,5m) an extended corridor of 100m wide. We have used resistivity and magnetic for that purpose. For the detection of voids, EM measurements were performed down to a depth of 6 meters (DualEM, 6 depths of investigation from 0,5 to 6m). Collecting of data, processing and interpretation of all sets of data was done through a GIS in a field and a web-GIS in the office. Resistivity showed perfectly well all artifacts linked to the battle fields (trenches, bombs and mines craters, old lanes, which were further correlated to old maps and drawings of the Allied Forces), but also the existence of pedological processes and some archaeological sites. None of these sites were evaluated nor excavated owing to the small impact of the project: special care was taken by RTE to minimize the mechanical effect of the displacement of their trenching machine in the field and the final positioning of the High Voltage Line was fixed taking into consideration all geophysical information.

In this last example, we see that it is possible in certain circumstances to gain some knowledge without destruction of the sites. We will see in the next chapter at which stage of the development geophysics is or can be used, the pros and cons of using geophysics in PA considering different point of views and finally the evolution of the role of the geophysics in the general scheme of development.

THE PLACE OF GEOPHYSICS: FROM RESCUE TO DEVELOPMENT-LED ARCHAEOLOGY

We have discussed earlier about the role of geophysics before archaeological evaluation. In fact, geophysics can also be used at 3 other steps of the development process: after mechanical evaluation, during or after archaeological excavations (Hulin *et al*., 2014).

Sometimes, after a 'positive' evaluation by mechanical trenching, state services need more information in order to define accurately the extent of the area to be prescribed for future excavations. Taking into consideration the price of excavations, any information at this stage is highly valuable. Geophysics can be of great help in this situation because the type and the depth of structures to be looked for are known. The only drawback is the destructuration of the area by excavators and the existence of trenches which prevent geophysicists to acquire maps contiguously. Of course, it is better to do geophysics before the trenches made by excavators. The second case of using geophysics which is nowadays the most seldom is to use it during excavation: for example detection and cartography of archaeological structures that are often difficult to "see" or detect in the excavation. The third case is the most common: when excavation stops, the archaeologists have no more time, nor permission to excavate outside the project. Geophysics can then be of great help to map the extent of the archaeological structures. Again, the type of structures to be looked for and their depth being known, this helps the geophysicist to choose the best parameters for his survey.

We will try to sum up in the next paragraph the pros and cons of using geophysics in PA.

Disadvantages:

- ✓ no datation and most of the time no idea of the state of preservation,
- ✓ no direct detection of small structures at great depths and of very early structures (Paleolithic),
- ✓ Not applicable in urban conditions,
- ✓ Difficult selection of geophysical instruments and parameters to use because targets are not known in advance.

Advantages:

- ✓ Preservation of archaeological structures (non invasive methodology),
- ✓ Evaluation is done over 100% of the project as opposed to 10% with mechanical trenches.
- ✓ Better definition of the archaeological risk assessment, even before the financial acquisition of the land,
- ✓ Very short delays because geophysics is quick (4ha/day with 1 single operator),
- ✓ Better work conditions: less time is spent in the field and more in the office.

- ✓ Can be used for a better positioning of trenches both for Archaeology and Geotechnical Engineering works,
- ✓ Possible knowledge of the archaeological structures outside the project,
- ✓ Delimitation of accumulation/eroded zones (geomorphology, specially for Paleolithic times),
- ✓ All documents produced are directly integrated in a GIS,
- ✓ Geophysical information can be used for other different topics (demining, water infiltration, detection of voids, of clayey areas, etc.).

CONCLUSION

As opposed to an old debate in France between archaeological evaluations with mechanical trenches and/or other techniques, we want to stress that geophysics, as aerial photos, LIDAR, for example is just another layer of information which contributes to a better detection and eventually mapping of our heritage. This point was already highlighted in the result of the European project PLANARCH (Hey and Lacey, 2001). But the evolution of geophysics to "motorized geophysics" since the PLANARCH project, has not only resulted in a higher spatial resolution, but also in a lower cost per hectare that makes possible the use of several geophysical techniques over the same area, optimizing the chance of detection. Consequently, we believe that geophysics has evolved so quickly in the last fifteen years that it can now be really helpful, not only for traditional excavations where its use is no more questioned, but also for PA (Dabas *et al*., 2005).

Finally, according to our experience, we must stress that Archaeology is just part of the process of risks assessment of any project whatever its size, from a real estate to a motorway. We have developed since a few years a new approach (ZSCAN®) where all information gathered within a project is shared through a web-GIS among the different actors of the development: we have seen in the case of RTE how the geotechnical risk assessment of voids can be used by archaeologists. We could also speak about UXO detection, water infiltration studies, pollution studies, that could be used by archaeologist and vice versa and that, is extremely useful for the design of the project.

In conclusion, Archeologists are not alone in the general process of risk assessment!

Addendum:

ARP®, AMP, EMP: 3 geophysical techniques for mass data acquisition in PA.

Geocarta has developed several systems for data acquisition in the field using either electrical fields (ARP®), magnetic fields (AMP) (see figure 3) or low frequency electromagnetic field (EMP). High frequency EM (or GPR: Ground Penetrating Radar) is not yet sufficiently developed to be economically deployed for the industrial scales encountered in PA. For PA, a mimimum of two technologies is used at the same time (ARP® and AMP). When knowledge of geomorphology is sought or deep targets (>2m), EMP is also used.

All these techniques share in common: a high spatial sampling density along the profiles (a few decimeters), a maximum distance between profiles of 1m, a centimeter-real-time navigation system (RTK GPS), a real-time acquisition Quality Check (QC), motorized platforms to tow the instruments, the possibility to survey at minimum 3 ha per day (ARP®, 8ha AMP or EMP) (Dabas, 2009).

Figures

Figure 1: Apparent MS map with Geonics EM15, A77 motorway.

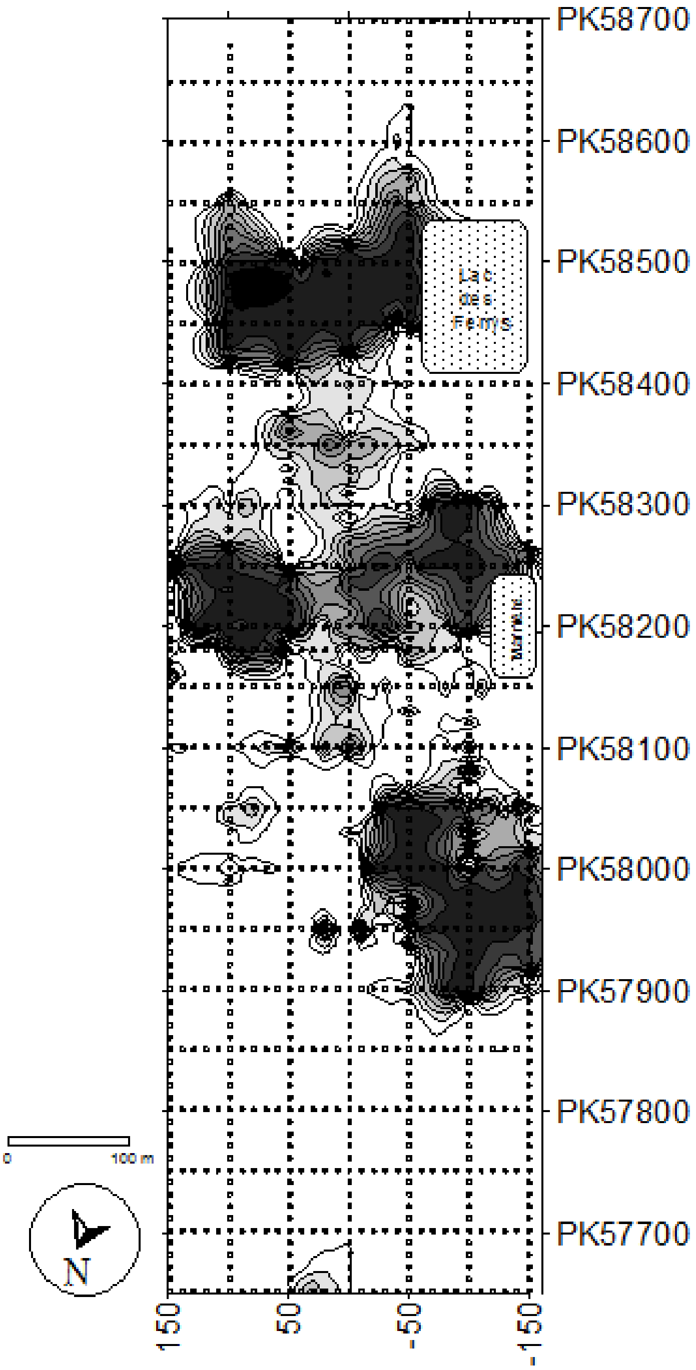
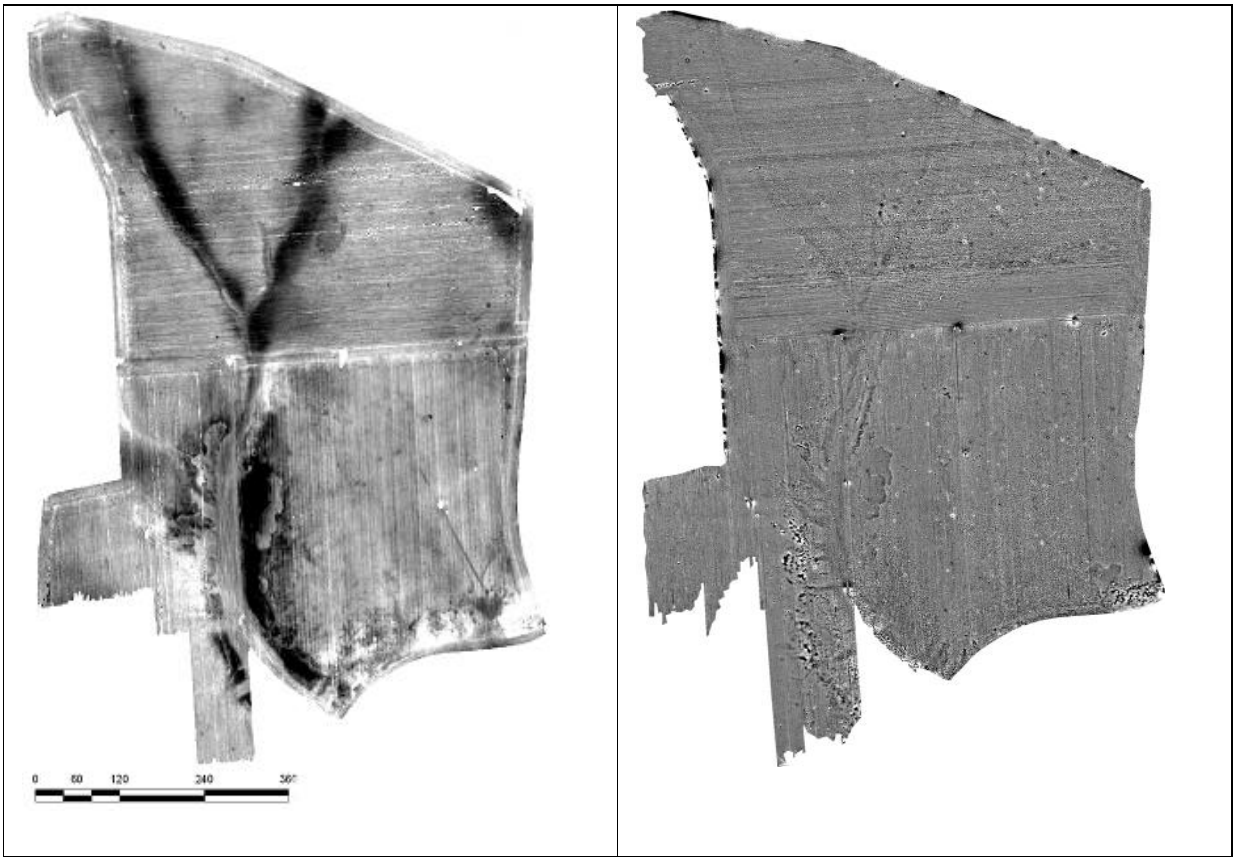


Figure 2: Apparent resistivity (left) and magnetic map, Vemars Project



If this figure is not clear enough I can replace it with one of Brebemi if Stefano has not already put it in part… example (necropolis, with ground truth):

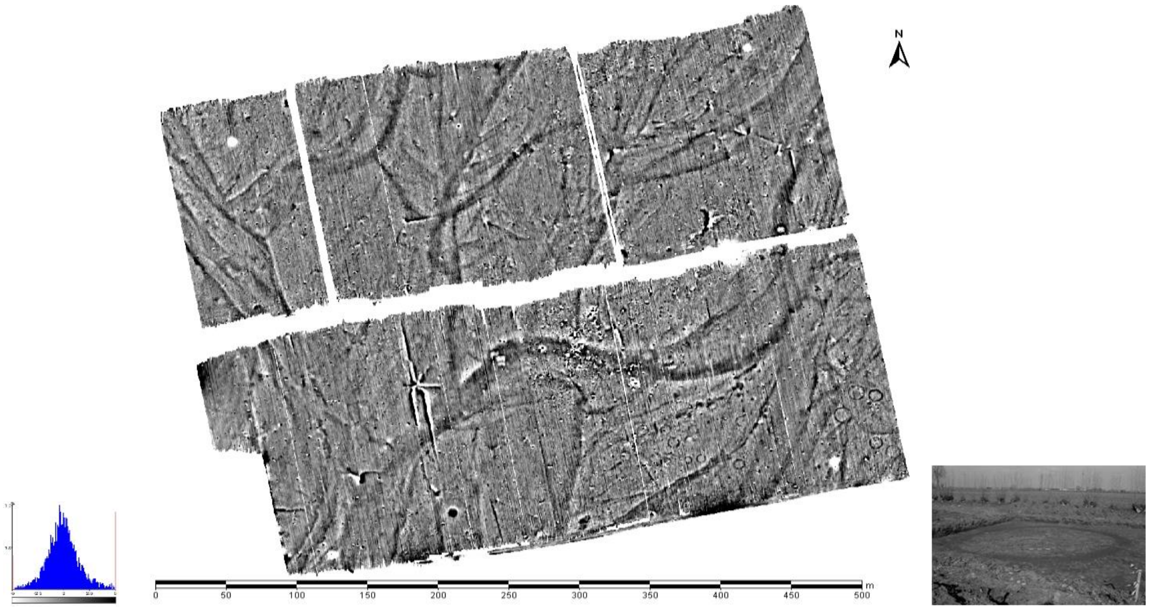


Figure 3: ARP® (left) and AMP (right) at work

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