Doerr, Martin and Apostolis Sarris (eds) 2003. The Digital Heritage of Archaeology. CAA2002. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 30th CAA Conference, Heraklion, Crete, April 2002.

An Association of Computerized Data Processing, Image Processing of Aerial Photographs, GPS Measurements, GIS: The Princely Site of Vix and Its Surroundings.

Laure Saligny[1] and René Goguey[2]

[1]UMR 5594
Pôle Géomatique – Maison des Sciences de l'Homme
Université de Bourgogne
21 000 Dijon
laure.saligny@u-bourgogne.fr
[2]UMR 5594
4, Rue Colonel Marcaire
21 000 Dijon
rene.goguey@libertysurf.fr

Abstract. An association of computerized data processing, image processing of aerial photographs, GPS measurements, GIS : the princely site of VIX and its surroundings. The aerial researches in archaeology which have been carried out for about forty years in France by a team based in Dijon, have generated more than 60 000 pictures. The management, processing and conservation of such a huge number of documents make compulsory the use of computers for digitization, image processing, classification, cartography. The example considered here deals with the princely site of Vix and its surroundings, as part of a common program of international interdisciplinary research. Such an archaeological study about a territory requires the inventory of the sites and their characterisation. In this context, the contribution of aerial photography is essential. The study of Vix and its surroundings was done partly through the setting up of a GIS, which demanded the integration of the archaeological data gathered through aerial photography.
The mode consists in organizing the archaeological data revealed by aerial photographs. This requires the definition of a mode of operation to extract the information of the photographs and integrate it into a GIS. The mode of operation falls into several parts: GPS acquisition of the control points on the field, rectification of the aerial photographs, georeferencement of the aerial photographs, digitization of the visible archaeological structures and integration / organization in a GIS This study about Vix is a relevant example of how to manage and use data made up of aerial photographs through the association of several methods and tools.
Keywords. Aerial photographs, GIS, GPS, "Exact-fitting", Rectification, Geo-referencing

Introduction

The discovery, in 1952, of the Hallstatt tomb of the "Princess of Vix", with its giant krater, chariot and gold jewelry, is what has made this upper Seine valley a major site in European proto-history. As the site's discoverer, René Joffroy, published his thesis on the Vix oppidum (R. Joffroy, 1960), a major aerial recognizance program was beginning, remarkable both for its longevity (over forty years), and for the substantial means it required. Although Vix and the chatillonnais area represents only a tiny part of the prospection zones covered in France (from the Loire to the Rhine) and those in Central Europe (the Czech Republic and Hungary), positive results were rapidly obtained, both on the terrace of the princely tomb and in the surrounding area (R. Goguey, 1968): Bronze Age and Hallstatt circular enclosures; Late Iron Age four-sided funeral enclosures; a large square enclosure that Bruno Chaume's excavation identified as a Hallstatt sanctuary; traces of proto-history dwellings; and Gallo-Roman villas. These new excavations on the Vix site led to a thesis published in 2001: "Vix et son territoire à l'âge du Fer. Fouilles du Mont Lassois et environnement du site princier" In which Bruno Chaume after a critical study of the data from previous excavations, produced a model for the site with three concentric rings around the princely residence, (B. Chaume, 2001). A collective research program (PCR) led by Professor Mordant is underway, associating French researchers, German archaeologists from Kiel and Bade-Wurtemburg, and an Austrian team from Vienna.

Figure 1. *View of Mont Lassois and princely site in the foreground (R.Goguey).*

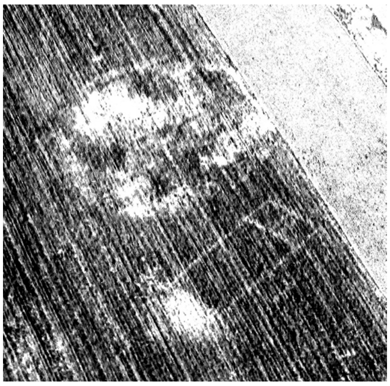

Figure 2. *The princely tomb (R.Goguey).*

This is therefore the archaeological and scientific context in which we work in collaboration with the main actors in this project to set up a GIS.

GIS description: aims

In the long term a GIS aims to organize and manage all existing archaeological data (of all periods) for the Chatillonnais area in a single database.

There are many types of data available: diverse computer databases, aerial photos, geophysical prospecting, topographical surveys, GPS surveys etc. The GIS is used to collect all of them and integrate them homogeneously into a single database in order to provide researchers, in a simple and effective way, with the necessary information to answer their questions.

Over the next three years the aim for the GIS is to work on the relationship between habitat and necropolis in protohistoric times and on the geographical and chronological links with Vix. For the moment there is no other known settlement apart from Mont Lassois although the cartography of burial grounds is extensive. Research will therefore be centered on finding settlement sites.

There will be three stages to our research strategy.

- The topography and cartography of tumuli. An inventory of all such sites in the Chatillonnais will be drawn up. Prospecting around known tumuli may lead to the discovery of others. All burial grounds will be surveyed by tachometer or GPS in order to create a geographical database in the GIS.
- The cartography and inventory of ancient trade routes: photo-interpretation and carto-interpretation will be useful tools for this.
- The creation of a model after field-tests with geophysical and on site prospecting to create a cartography of potential settlement zones.

The criteria for settlement discovery are:

- proximity to burial grounds.
- proximity to trade routes.
- geomorphologic context.
- nearby water sources.
- site positioning around the configuration: valley, slope and plateau edges.
- the proximity of mineral ore.

GIS database description

The GIS database is under development. Access is the semantic base. ArcView manages the geometric data. Each object (site) has the same identity tag in both ArcView and Access, which allows all relevant data to be found.

A central base manages all sites. On small scales, point entity or geographic form is used for cartography. The site identity tag links it to the other databases. They are for the most part a large-scale cartographic representation using various geometric forms such as points, lines and polygons.

Within the framework of the GIS, all the archaeological information acquired on the Chatillonnais region from different sources should be brought together and organized to offer researchers a corpus of sites as homogeneous and complete as possible.

Aerial photography treatement

With this aim in mind, a method of integrating aerial prospecting data has been developed. It operates on two axes: the creation of the database and the technical means for completing the database. Aerial data must be integrated and usable on large and small scales.

For small-scale work, we use Mr Goguey's database, in which each photo is geo-referenced by coordinates: rapid thematic cartography is therefore possible.

Computer technology in aerial data collecting:

If to begin with the study of aerial photographs was rather a manual craft, the data is now so abundant that computer technology plays a major part in data-processing. Plotting points by hand on the map has been replaced by GPS localization after vertical on-site photography. A digital site map can therefore be quickly created, either after each flight, or at the end of a campaign. Digital photography has been tested successfully: photographs taken with professional quality 6 million pixel cameras are as good as those using silver film, or even better when processed with Photoshop and interpreted with Illustrator. This treatment can be used on films of all types, including infra-red films, which are optimized after digital scanning by recentring, zooming in on details, increasing contrast, saturation and reinforcing by filters. Crop marks have been brought to light on old photographs taken in poor conditions, and on black and white vertical photographs of the princely tomb region around Vix. The documents thus collected – 60,000 aerial photographs on the scale of a global prospection program – are organised in an Access databank giving the geographical coordinates, the date of photography, the description, and a characteristic color photograph for each site.

One of the main reasons for using aerial photography is to get a precise plan of the site, its structures and internal organization. Aerial photography allows a thesaurus of site plans to be developed, which could otherwise only be obtained by excavation. The objective is therefore to compare these plans with each other and learn more about the structural organization of the territory by cartography. In order to do this, the aerial photos must first be rectified, to recreate a perpendicular view, and to create a uniform scale.

To establish a GIS, archaeological data from the interpretation of aerial photos must be integrated into the database, in order to overlay the data with other environmental and archaeological data. Therefore the data must be geo-referenced using the same system of co-ordinates as the GIS (Lambert II étendu).

The method used has three stages: rectification, geo-referencing, and digitizing (image interpreting) with the creation of a geographical database.

The 'exact-fitting' of aerial photos by GPS control points:

The stage that we call 'exact-fitting' links both rectification and geo-referencing.

Although by definition these are two separate stages:

- rectification: as the photos are taken at an oblique angle, visible elements are not true to life (surfaces, distances and forms are more or less erroneous). Rectification therefore deforms photos to give a vertical perspective.
- geo-referencing: This allows the photo to be adjusted to fit a geographic reference (to situate it in a system of projection). Amongst other functions, this brings the photos back to the desired scale. They are therefore reduced or enlarged so that all the photos can be overlaid, and can also be overlaid on other geographical databases

Why used GPS for "exact-fitting"?

Whether for rectification or geo-referencing, a frame of reference is required in which 'exact-fitting' of photos is in relation to a minimum of four control points.

Rectification is generally performed in reference to the land register (cadastral survey): boundaries visible on the photo are 'exact-fitted' in relation to land register boundaries. However there are several drawbacks when using the land register. Firstly, in the Chatillonnais, you must get hold of the maps, and then scan them. That wouldn't be too bad, but then they have to be geo-referenced. And in France in some areas it is difficult to link maps, as there are many errors in Lambert control points in the land register. So other 'exact-fitting' points are necessary for geo-referencing. Another possibility for 'exact-fitting' would have been the use of very large scale digitized geographical databases. Unfortunately there are none of the Chatillonnais region.

To sum up, as there is no commercial database solution available, and as the geo-referencing in the land register is inadequate, we have chosen to use the GPS.

This has been made easier by the University of Burgundy, which has acquired two Trimble GPS ProXrs for use by researchers. These GPS function in differential mode and allow centimetric accuracy. So we decided to survey in the field certain landmarks visible in the photos.

This is doubly interesting:

the same method is used for all aerial photos. The data will thus be equivalent and comparable to each other.

the same control points are used for rectification and geo-referencing. Errors in precision are therefore avoided.

Results : limits and perspectives

The method was tested in July 2001.

The main constraint for rectification and geo-referencing of aerial photos is the necessary selection of these photos. Whatever control points are used, whatever their origin, they must not only be visible on the photo but also spread out equally over the whole photo so that rectification will be homogeneous. This is why many photos are rejected: if, for example, there are not enough control points or recognizable landmarks (under 4), or if they are concentrated in a single area. This is particularly the case with large-scale photos, (zooming in to the site) where no boundaries are visible.

Furthermore, to avoid complex treatment, the selected photos only represent a flat topographical sector, with no gradient. Altitude is an important factor in rectifying aerial images, but it is more difficult to use: more reference points are needed, for example. Therefore to begin with we hope to test the simplest method first.

26 photos were selected for 12 sites. Fieldwork covered all 12, but only 5 were surveyed.

The main limits to this method are problems arising from environmental, agricultural and land ownership reasons:

- some areas are inaccessible because of crops (rapeseed, wheat, etc.) nearing harvest, or the presence of dangerous animals such as bulls or bees.
- As some land restructuring has taken place, boundaries in the photos may no longer exist. This is the case for the older photos, from the 60s and 70s.

GPS is easy to set up on site and easy to handle. From base set up to point referencing, it takes about 45 minutes to analyze a site. Various types of identifying points may be used: plot corners, electric posts, crossroad intersections, trees, etc. Accuracy varies from 10 to 30 cm. Greater accuracy may be attained by increasing exposure time at each point.

Figure 3. *Navette site – Original photo (R.Goguey).*

Figure 4. *Navette site – Original photo (R.Goguey).*

After exact-fitting aerial photographs and overlaying them with other data, a relatively high ratio of coincidence is obtained for visible topographical elements (streams, roads, etc.) (fig.5). The more so as the geographical databases used are decametrically precise.

The worst ratios are mainly due to a problem in the choice of "exact-fitting", as it was not possible to choose control points around the photo or even the site itself. As rectification can only be performed with control points, the best option is to have at least 4 points forming a quadrilateral around the image or even the site.

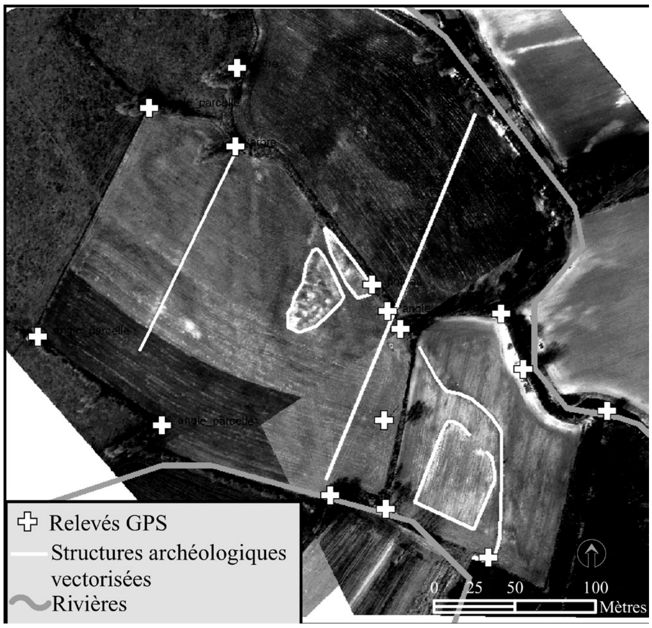

Figure 5. *Navette site : the result after the "exact-fitting".*

In order to test various methodological approaches (and to avoid limitations), some test cases were "exact-fitted" in relation to other previously rectified and geo-referenced photos. Some photos shot on too large a scale where treated either directly in relation to another photo (digital superpositioning of two photos by common point indexing) or by points digitized from a reference image (fig.6).

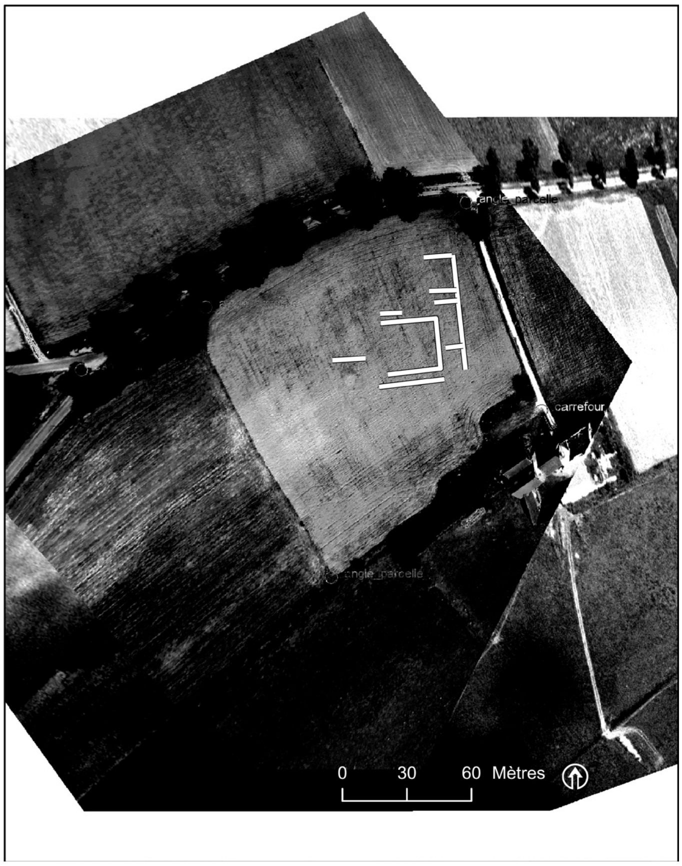

Figure 6. *Fontaine's Villa : a superpositioning of 2 photos.*

On the other hand, we extrapolated plot angles (GPS identification) to make up for the lack of identifying points (fig.7).

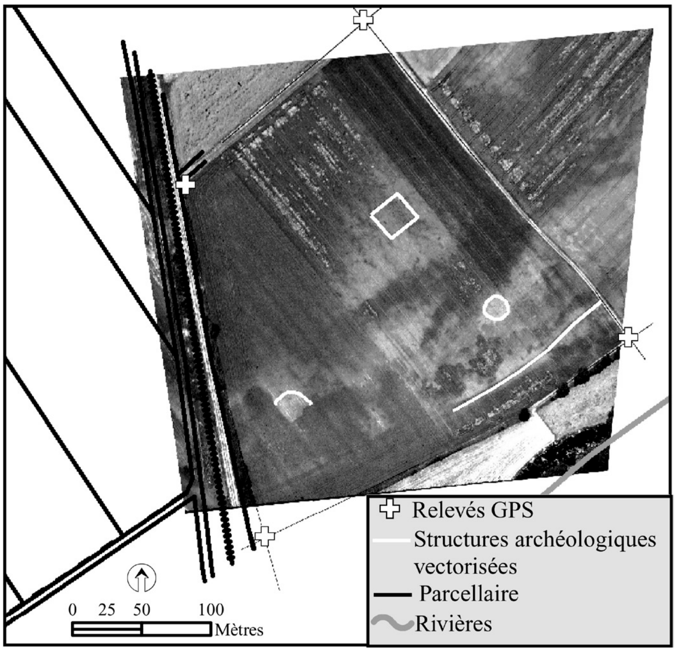

Figure 7. *Herbues's site : points extrapolation.*

Perspectives:

- use of the same reference coordinates at each stage (rectification and geo-referencing)
- ease and speed of use on site and in the lab for the post-treatment

- an optimal number of photographs to be treated by choosing the best season for fieldwork
- surveys and ground prospecting together may save time and allow new information such as site dating to be obtained

A geodatabase with archeological structures conception

The final phase of this process is the creation of a database of all digitized structures derived by photo-interpretation (Fig 5, 6, 7). The database is built for large-scale analyses, topographical site studies and comparisons. Therefore all structures visible on aerial photographs are entered into the database. The structures are digitized using ArcView.

For geometric description, line entities were chosen: all traces will be indicated by lines not by points or polygons. This may create problems with future analyses or requests: surface area calculations will not be directly possible in the case of enclosures for example.

However the use of lines allows forms to be traced, which is not the case with points or polygons: the latter cannot be used with open forms. Moreover, lines can be interpreted over a broader range of scales than polygons.

The information to be stored in the database for each archaeological item is as follows:

- an identify tag within the GIS Vix database
- the archeological interpretation
- the identify tags of the photos on which the structure was digitized
- the identify tags of the photos on which the structure can be seen
- the estimated dating

Links are established between this database, the main GIS database and the aerial photography database, through the various identify tags.

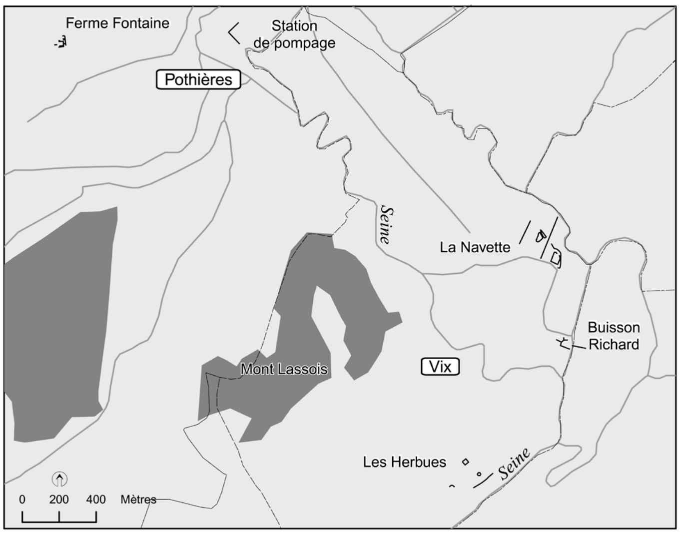

Figure 8. *A site distribution map.*

This geographical database of archeological structures drawn from photo-interpretation allows site distribution maps (with structures) to be created (fig.8) and site analysis to be performed. The use of GPS adapted to "exact-fitting" tools allows archeological structures to be recorded with a view to topographical study and inter-intra site comparison.

In conclusion, GIS is in its initial phase. After testing the tools and establishing a work procedure, we must now integrate all the data, a lengthy but essential phase before moving on to analytical treatment.

Acknowledgements

Many thanks to Claude Mordant and Bruno Chaume for their trust and their encouragement.

References

BRUN, CHAUME (dir.), 1997. Vix et les éphémères principautés celtiques. Les VIème et VIIème siècles avant J.C. en Europe centre-occidentale. Coll., Châtillon-sur-Seine, 27-29 Octobre 1993, Paris, Errance, 408p.

CHAUME, 2001. Vix et son territoire à l'âge du Fer. Fouilles du Mont-Lassois et environnement du site princier, Montagnac, Librairie archéologique, 2001, 643 p, 230 ill. 155 pl.

CHAUME, GOGUEY, REINHARD, VAN DER OSTEN WOLDENBURG, 2000. « Découvertes autour de Vix », Archéologia, 366, Avril 2000, p.12-25

GOGUEY, 1968. De l'aviation à l'archéologie : recherches sur les techniques et les méthodes de l'archéologie aérienne, Paris, Ed. Technip, 1968, 128 p. 63 pl.

JOFFROY, 1960. L'oppidum de Vix et la civilisation hallstattienne finale dans l'Est de la France, Paris, Ed. Les Belles Lettres, 1960, 210 p. 81 pl.