12000 years of human occupation, 3 meters deep stratigraphy, 12 hectares... A geographical information system (GIS) for the preventive archaeology operation at Alizay (Normandie, France)

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12000 years of human occupation, 3 meters deep stratigraphy, 12 hectares… A geographical information system (GIS) for the preventive archaeology operation at Alizay (Normandie, France)

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Abstract

An archaeological investigation carried out by INRAP (Institut national de recherches archéologiques préventives) revealed that banks of the river Seine at Alizay (Normandy, France) were occupied during 12000 years. The specifications of the excavation were to study various occupations (Upper Palaeolithic, Neolithic, Iron Age and Middle Age) applying the appropriate methodology for each major period.
A Leica TS15 robotic total station was used to rapidly record archaeological features and store directly in the field pre-formatted GIS data. The aim of the process was to inventory and study, during the excavation, the 120 000 exhumed artefacts using a Microsoft Access database linked to a geodatabase in Esri ArcGIS.
This specific archaeological information system was designed to guide the earth removal, by producing digital elevation model of each stratigraphic context, facilitate the management and inventory of artifacts and spatialize the data produced during the excavation.

Keywords: Preventive archaeology, GIS, Process, Methodology

1. Introduction

An archaeological operation carried out by INRAP (Institut national de recherches archéologiques préventives) revealed that banks of the river Seine at Alizay (Normandy, France) were occupied during 12000 years. In an extensive area of 12 hectares, archaeologists had to excavate a three meters deep stratigraphy covering the Middle Age, the Iron Age, the Neolithic, to finally reach the earliest settlement from the upper Palaeolithic (Marcigny et al., 2013). The specifications of the excavation were to study these various occupations applying the appropriate methodology to each major period.

A Leica TS15 robotic total station was used to rapidly record archaeological features and store directly in the field pre-formatted GIS data such as number ID, stratigraphic unit, nature of the artefacts, etc. The aim of the process was to inventory and study during the excavation the 120 000 exhumed artefacts using a Microsoft Access database linked to a geodatabase in Esri ArcGIS.

This specific archaeological information system was designed to guide the earth removal, by producing digital elevation model of each stratigraphic contexts, facilitate the management and inventory of artifacts and spatialize the data produced by specialists such as palynologist, malacologist, geomorphologist, geophysicians, finds specialists (lithic, pottery), etc.

Beyond technical and methodological aspects, this GIS is aimed to produce new data that could enrich our understanding of human occupations at Alizay like habitat, burials or activity areas, through time.

The present publication will explain the entire archaeological data process insisting on its different steps such as field recording, database design and management as well as GIS use for a large scale archaeological excavation.

2. Site specification

Situated in front of the city of Pont de l'Arche, in Normandy (NW of France), 40 hectares on the right bank of the river Seine, were archaeologically investigated, by B. Aubry, in 2007 and 2009. It revealed the high archaeological interest of this alluvial plain (Aubry *et al.*, 2011). 12 ha of this area located on the territories of the villages of Alizay and Igoville (Eure) were directly concerned by the future exploitation of gravel quarries owned by Lafarge and Cemex (Figure 1).

The presence of gravel under 3 to 4 meters of alluvial deposits, sealing human occupations from the upper Palaeolithic to the Middle Age, has required a preventive archaeological excavation conducted by INRAP in 2011 and 2012 during one year and half. More than 70 people were involved in this project which represents approximately 7000 man-days. Up to six 24t caterpillar excavators were employed at the same time during the digging as well as to remove 275 000 m3 of earth.

The scientific aim of the operation was the detailed study of the pre-and protohistoric occupations applying a multiscalar approach. The four main topics are focusing on the stratigraphy (the different deposits and the study of their evolution), the palaeoenvironment, the human occupation from a cultural and a chronological point of view and the

FIGURE 1: AERIAL VIEW OF THE EXCAVATION (H. PAITIER).

palaeoethnology. In order to address these questions, a multi-proxy study has been set up involving molluscan analysis, charcoal analysis, geophysics, zooarchaeology, palynology, geomorphology, sedimentology and micromorphology.

The archaeological investigation revealed the presence of 2 700 archaeological features (hearth, postholes, graves, oven, ditches, etc.) associated to 114 000 artifacts (68 000 lithics, 34 000 ceramics, 800 metallic finds, etc.). 110 different occupations or settlements have been identified and put into a chronological context by 180 C14 dating.

3. Methodology

Regarding the stratigraphy, the extent of the study area, the volume of earth, the schedule and the amount of data, the issue of the data recording process appeared as a cornerstone of this big scale excavation. A specific

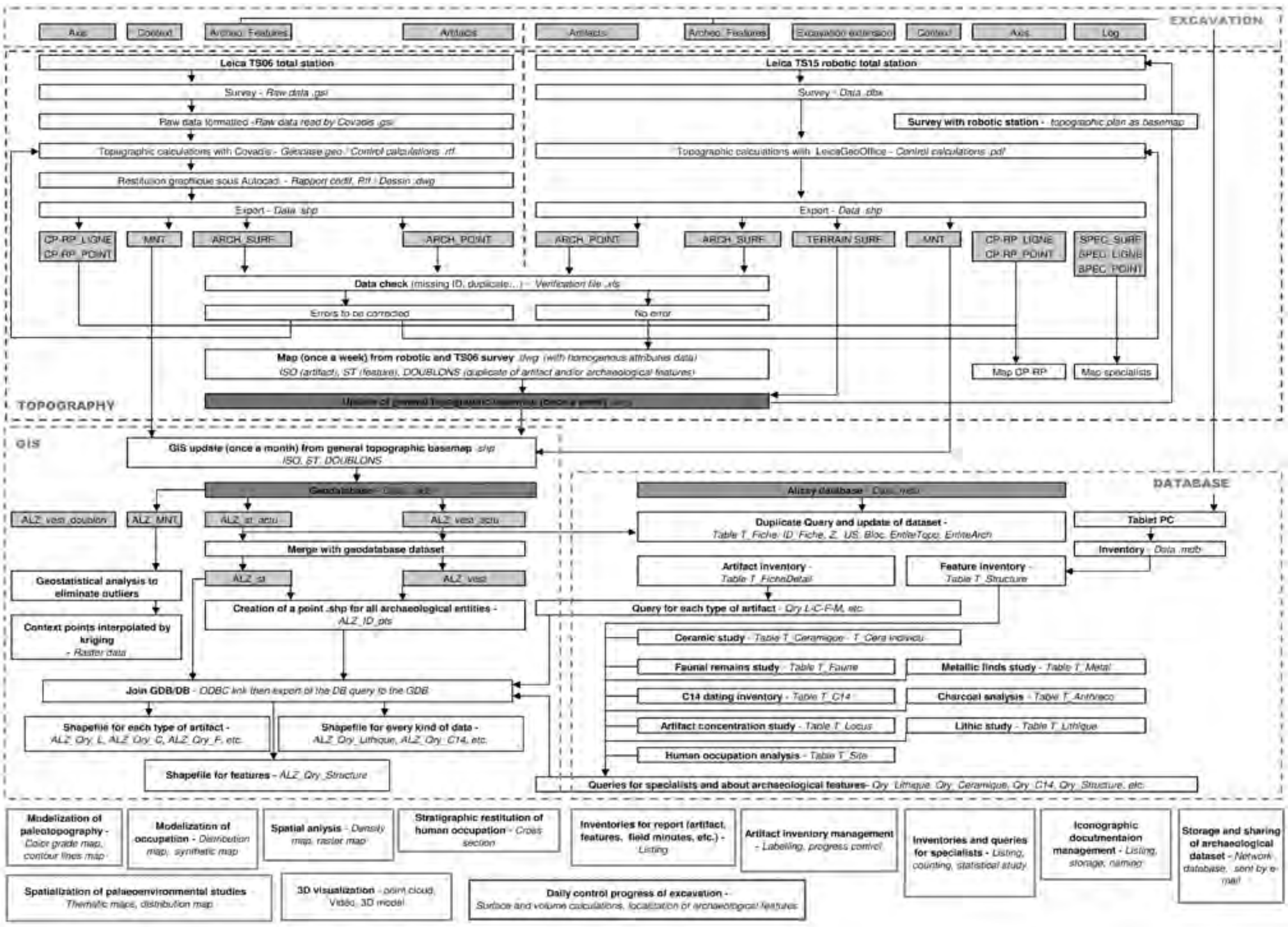

FIGURE 2: ALIZAY DATA RECORDING AND ANALYZING PROCESS.

methodology had to be set up to answer the followings questions:

– How to deal with so much data?
– How to record, describe, store and spatialize the data?

In the field, the topographical recording has to be efficient and the archaeological recording exhaustive. In the office, the operation needs to have a sustainable archaeological data archiving and the archaeological and palaeoenvironmental data must be spatialized.

A solution is to use a robotic total station for the topographical recording, a database to store the data and a GIS to spatialize these data. In this robust process of data recording, each archaeological remains (artifact or feature) has to be defined by a unique ID from 1 to n. This number identifies the graphic entity recorded by the topographer, the archaeological feature (using a label), the description of this feature in the database, the entity in the GIS which will be linked with this ID to the database through an attribute join.

The methodology used during the field investigation is shown in figure 2. This chart is composed of five parts showing the five steps of the data recording process.

First of all, we have to identify and conceptualize what has to be recorded in the field. The 3D position of the artifacts and position of stratigraphic units can be represented by points. The shape of archaeological features or the extent of trial trenches or boundaries of the mechanic overburden removal are drawn with polygons. Finally, the axis of cross section is represented as a line.

The topographer is in charge of recording the features in the field. His job is to rapidly record, all day long and accurately the features and allocate an ID to each feature. In the office, he will verify the accuracy of the recording, control errors such as duplicates or missing information and he will produce plans on a weekly basis. Two to three topographers have been employed during 288 days, recording 80 000 different features

Centimetre accuracy in the three dimensions and a control of this precision were required for the topographical equipment; for these reasons, we used a total station instead of a GPS device.

On the other side, it has to be a robotic device (Leica TS 15) which allows to record natively all the features enumerated above as point, line or polygon. The standard total station Leica TS06 used at INRAP can not do the same: a codification has to be used in Geomedia COVADIS, a plugin software in Autodesk AutoCAD which will draw line and polygon from the point cloud recorded in the field. It is not the only benefit of the use of the robotic total station in comparison with the standard equipment; we could cite the autonomy of the topographer during the work, real-time topographic computing, the visualisation of maps in the field, and the possibility to record different descriptive data linked to the graphic entity. As a matter of fact, we were able to record for each archaeological feature their ID, the stratigraphic unit to which it belongs, the nature of the artefact, and additional comments. A data dictionary was designed in Leica Geo Office for this purpose and upload in the Leica CS15 and its software Leica SmartWorx Viva.

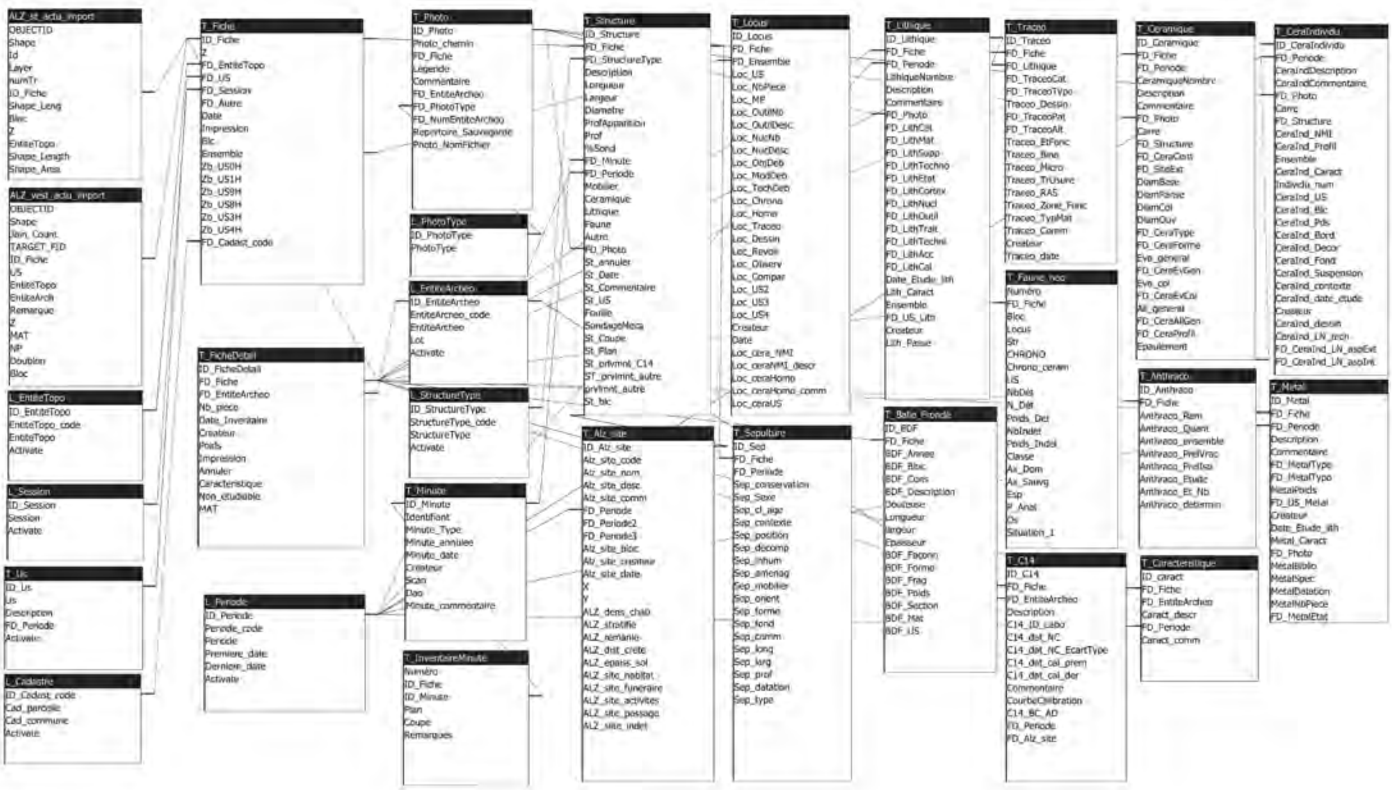

Figure 3: Simplified relation table of Alizay database.

The keypoint of the use of the robotic total station is the normalization of attribute data directly in the field which then allows a GIS export of topographical data as an ESRI shapefile. This format which could be read by Autodesk AutoCAD, Leica Geo Office and of course Esri ArcGIS provides a good interoperability between software used in this process.

The use of two different total stations, a robotic one and a standard one, prompted two different processes as seen in figure 2. The one used with the robotic station is shorter than for the standard station. The latter requiring more steps to produce the same quality of topographical data, which is then used for the GIS update.

Just before this update, the dbf file from the shapefile containing topographical data, is used to check duplication or incoherence in the data set. 'Alz Verif Topo' is a VBA routine developed in an Excel file by P. Boulinguiez, one of the topographer of the operation, which reads one or several dbf files and check duplicates of feature's ID, errors in the z value regarding a fixed range of heights, jumps in the ID numbering or missing information (stratigraphic units or nature of artifacts). A report is then produced, summarizing the different problems which can be displayed or printed in order to proceed with modifications to the data set.

In parallel with the recording of the graphic entity, the archaeological recording has to be done in both the field and in the office. A tool for the whole team is necessary, with the possibility of describing single item or a batch of items and to store interdisciplinary data. The 'Alizay' relational database has been designed with Microsoft Access, ensuring a good interoperability with a geographical information system and a light weight storage file. The database of the project weights 60 MB whereas a zipped version represents only 13 MB: sharing of data between members of the project is facilitated even by e-mail.

Most of the time during the operation, archaeologists were working at the same time on a network database which was stored on a network area storage (NAS): the aim was to avoid redundancy of information. The database was used to inventory artefacts and produce labels for archiving but also for specialists to store studies about

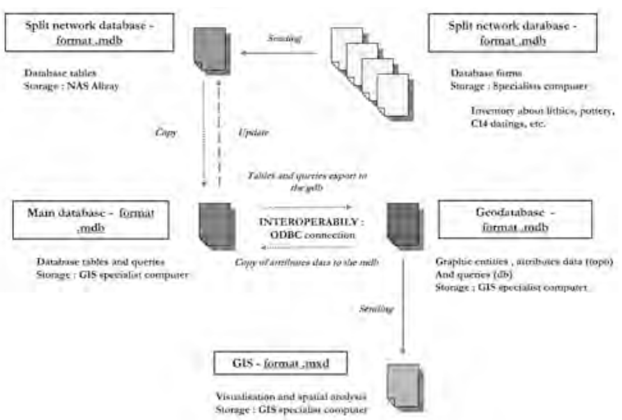

Figure 4: Architecture of Alizay process.

lithics, pottery, charcoals, anthropology, C14 dating, etc. The archaeological features were registered directly in the field through a lighter version of the form designed for a tablet PC.

Figure 3 is a simplified version of the relation's table of Alizay database where the primary key of most of tables is the unique ID used to define archaeological features. New data created from the survey on a monthly basis, is loaded in a generic feature layer ('ALZ_artefact_update') from the vector geodatabase of the project and linked permanently to the Alizay database through an attached table. This is possible because the Esri geodatabase is a mdb. file and appears as a Microsoft database file. It allows to harvest topographical data concerning ID, type of artefact, geographic coordinates (X, Y and Z), stratigaphic unit, cadastral parcel ID, remarks, etc. These data are stored in a specific table called 'T_Fiche' table, the main table of the database. Data derived from artifacts inventory ('T_FicheDetail'), from specialist studies ('T_Lithique', 'T_Ceramique', 'T_Anthraco', 'T_BalleDeFronde', 'T_C14' etc) or from archaeological feature analysis (T_structure) are linked to the main table. Photos or scanned and vectorized drawings can be displayed into forms related to artefacts or archaeological features: a relative path is stored in a specific table but not the picture itself otherwise it will increase the size of the database.

Basic queries have been designed in order to be exported to the GIS. The aim is to present the distribution of the different type of artifacts ('Qry_L' for lithic, 'Qry_C' for pottery, 'Qry_F' for faunal remains, 'Qry_M' for metallic finds, etc.), the density of artifacts or features according to the stratigraphic unit or the chronology ('Qry_St_NEA' for the structures dated from Early Neolithic, 'Qry_St_NEM for the structures dated from Middle Neolithic, etc.)

The GIS of the project is composed of a vector geodatabase and a raster geodatabase, in order to improve the management of data. A personal geodatabase has been set up to store rasters such as topographical and geological maps, Lidar or aerial imagery, DEM produced, georeferenced photos, old maps (Napoleonic cadastre, atlas of Trudaine, etc.).

The vector geodatabase stores all the graphic entities and their attribute data. As explained above, two specific feature classes were created to import new data derived from the topographic survey: one for the update of artifacts (point feature class) and one for archaeological features (polygon feature class). These two feature classes will be added on a monthly basis to the main feature classes containing the whole data set. In case of errors, duplicates or problem of versioning, entities are stored in two specific feature classes according to their nature (point or polygon).

A lot of different feature classes concerning archaeological evaluation, cadastral parcels, extent of the mechanic overburden removal, etc. are also stored in this geodatabase.

Joining attributes table to a large set of graphic entities in Arcmap (>100 000) can be very difficult in terms of display and labels. A direct join with a table stored in a database through an ODBC (Open Database Connectivity) link will crash but if the table is stored with graphic entities in the same geodatabase, then displays and labels will refresh as fast as with a small dataset.

Therefore, an ODBC link created in Esri ArcCatalog with 'Alizay' database allows importing queries designed earlier in Microsoft Access. This import is done automatically through a routine created in the modelbuilder of ArcGIS. Graphic entities and attributes data coming from the database are stored in the same geodatabase and then can be joined and displayed quickly in Arcmap.

As explain above, the whole process set up for Alizay operation requires a specific architecture to deal with a large dataset that has to be shared by different actors (specialists, topographer, GIS operator, etc.). Figure 4 shows how such a process can work with a network database and a GIS. The cornerstone of the process is the storage of the Alizay database and the geodatabase on the GIS operator's personal computer. Copies and updates are made from this database to and from the shared database on the network and to the geodatabase of the GIS. The backup of the most important data of the project can be done from the GIS operator's PC: Cobian Backup from Cobiansoft was employed to copy the Alizay database and

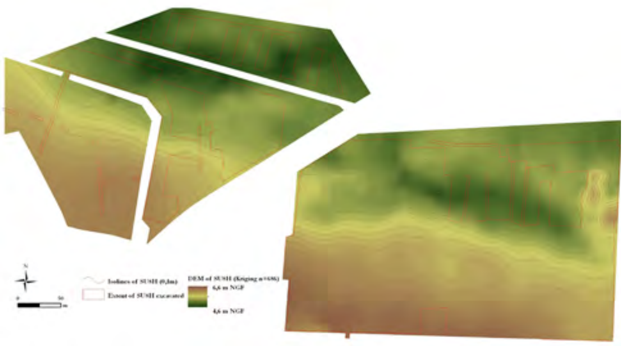

Figure 5: Modelization of a stratigraphic context (8H) of Alizay (interpolation by kriging).

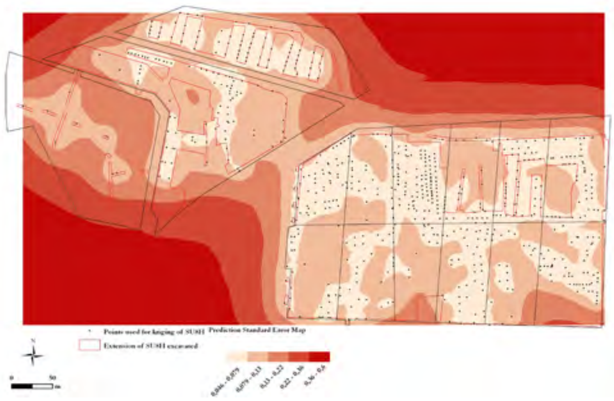

Figure 6: Standard prediction error map of the DEM (figure 5)

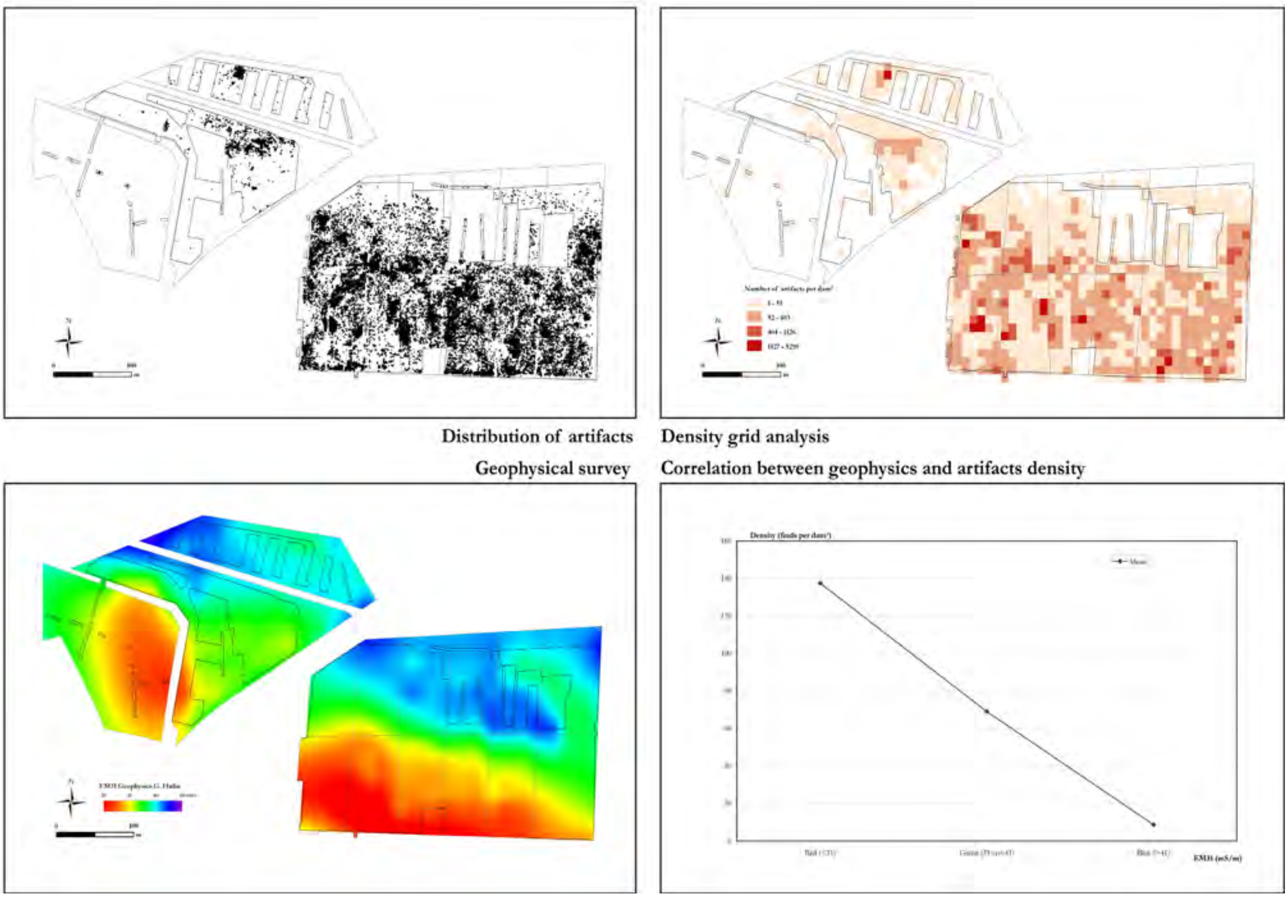

Figure 7: Alizay data recording and analyzing process.

the two geodatabases everyday on different support: NAS, hard disk drives and in the cloud.

The last section of figure 2 concerns applications of the whole process. For the topography, as explained earlier, the aim is to be able to produce maps showing the extent of the overburden removal, archaeological features and artifacts, on a weekly basis. Surface and volume calculation allowed accurate monitoring of the progress of the excavation.

The main interest of the database is to archive data in a safe and sustainable manner. When queries are set up, it provides up to date artifacts or features inventories which have to be present in the official report of the archaeological operation. It also provides statistics for specialist's studies. Moreover, the management of iconographic documentation is ensured by storing, listing and naming pictures and drawings.

Several GIS applications have been done during the fieldwork. One of the most useful was the production of DEM of excavated stratigraphic units exhumed. 2507 points have been recorded for five different archaeological layers. An interpolation of these points by kriging was run in order to reconstruct the paleotopography (figure 5). At the same time, errors have been quantified and spatially located to validate the model (see figure 6). The model was then used as a basemap for the paleoenvironemental reconstruction using multi proxy studies.

Another application was the use of the distribution of artifacts to run a density grid analysis (10x 10 m). This rasterization of artifacts distributions was then compared to the resistivity maps produced by the geophysical survey. The comparison revealed a lower density of finds in the clayish zone which corresponds to palaeochannels. At the opposite, higher density of finds are located where gravels are present, on ancients river banks (see figure 7).

We use also the GIS to apprehend the stratigraphic context through the display of artifacts point cloud in Esri Arcscene. We also produced vertical distributions of artifacts using a plugin called Crossview, a A-Prime Software: it projects finds on a cross-section created by data derived from DEMs. It appears to be a very good tool to understand successive human occupation located on a same spot.

4. Conclusion

As a conclusion, the deep stratigraphy, the presence of prehistoric settlements with significant number of finds, the time constraints and the scale of the project required a complex process to ensure the detailed recording of a significant amount of archaeological data.

This process made possible the excavation and the study of several occupations and sites like an Upper Palaeolithic settlement (9800-9300 cal BC) associated to long flint blades production and the butchering of six aurochs (Bos primigenus), several Middle Mesolithic sites (8th millennium) with geometric microliths (lunates), an Early Neolithic occupation represented by few pits containing a pottery of La Hoguette culture dated by C14 on bone temper (5370 – 5222 cal BC). One hundred hearths of the Middle Neolithic with associated flint and ceramic concentrations have been excavated; the river bank of the Seine appears at this time as an area of significant activity. A high concentration of artifacts and two series of postholes indicate the presence of two different habitations, close to each other and dated to the Recent/Late Neolithic. Several loci dated between 2400 and 2050 BC were found in the south-western part of the excavation. These consist of flint and pottery, some of them attributed to Bell beaker culture. During the Early Bronze Age II, geomorphology shows that the floodplain is well established and fords are appearing: near two of them, more than 250 sling stones have been discovered indicating a possible fight between Bronze Age populations. Two circular houses and several quadrangular structures (granaries?) associated with metallurgy indices (slag and melting-pot), revealed the presence of a Second Iron Age occupation. Finally, 15 m wide ditches with a depth of 4 to 5 meters have been identified in the north-west of the excavated area and belong to a quadrangular fortification. This feature is related to the fortified bridge of Pont de l'Arche (Eure), built between 862 and 873 AD by Charles the Bald, to stop the Viking raids. Ovens and a funerary group of 11 individual graves dated by C14, to the 9th century AD are completing this Early Middle Age occupation, whereas metallic finds (coins, weaponry, and clothing) show the use of the area until at least the 16th century AD.

The archaeological investigation carried out by INRAP at Alizay has widened the scope of the prehistoric and historic knowledge of Normandy while it improved methods in preventive archaeology by developing an original data recording process, which could be applied to other big scale archaeological projects.

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