KARTAGO as a Viewer of GIS- and Multivariate Archaeological Data in the Ajvide and Carrowmore Projects – The Full Concept

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Abstract

An aim to fully integrate available, digital techniques in archaeology, from remote sensing prospecting, computerized field registration, and documentation of data, mapping and landscape reconstruction, over classification, analyses, simulation and interpretation, to presentation and visualization in education and heritage management, was initiated in 1994 in two of the author's field projects: the excavation of the stone age settlement and burial ground at Ajvide, on the island of Gotland, in Sweden, and the Swedish archaeological excavations of the megalithic cemetery of Carrowmore, Co. Sligo, in Ireland. During the four-year period that has passed since the start, a series of applications and various softwares have been tested, and these experiences have gradually modified the original concept. It is now time to evaluate the systems that are in use on the two sites. It should be underlined, that a development of new applications is still on-going, and that the results here presented, should be regarded as a first step towards full integration. As the two sites present very different documentation problems, and consequently, also demand different approaches to analyses, interpretation and presentation, a brief description of each site is necessary.

Ajvide, Eksta Parish, Gotland, Sweden

The extensive, archaeological investigations of the Ajvide site have shed light on the importance of large-scale, remote sensing surveys and excavations, and the development of new and advanced, computer-based technology, for documentation and interpretation of archaeological materials. The settlement pattern and possible seasonality of the Stone Age at Gotland, including the pitted-ware tradition, as well as the relation between coastal and inland sites, are largely unknown. Also, the relationship between the coastal burial grounds and the settlements, from the pitted-ware tradition, have, by and large, remained obscure. The lack of modern, interdisciplinary investigations has conserved the notion of static, cultural groupings on the island, during the Stone Age.

The area of the Ajvide site is about 200,000 square meters, and it was used, more or less continuously, from the Late Mesolithic, until the middle Bronze Age, a period of around 4,000 years. The main period of use, however, was the Late Middle Neolithic period, between 3,000 BC and 2,300 BC, with a settlement occupation, between 3,100 BC and 2,700 BC. The coastline and paleolandscape changed, considerably during the period of use, as can be shown through total station-based, topographical mapping (Burenhult 1997a:IX-XXI). A major transgression, during the Early Middle Neolithic period, has been recorded at c. 2,900 BC, and most parts of the main, Middle-Neolithic activity area were submerged, for a short period of time.

The burial ground at Ajvide was located, by ground penetrating radar in 1983, and so far (1998), 58 graves have been excavated, containing well-preserved skeletons of individuals, of both sexes and all ages (Burenhult 1996, 1997b and 1997b). Several of the graves consist of double or triple graves, and in some cases, an adult individual has been interred, together with one or more children. The individuals in the graves seem to represent a complete society. About one third of the graves proved to be cenotaphs, containing no interred human remains, but often extensive, grave goods.

Another 9 graves completely lacked skulls or any cranial parts, and in most cases, it is likely, that the skulls were deliberately removed, before burial.

The burial ground, shown to have been used slightly later, than the main, pitted-ware occupation phase, c. 2,700 BC – 2,300 BC, was evidently designed as a ritual landscape, with a strictly planned layout, in which the graves formed a half-circle (or possibly, an oval), surrounding an open area, containing a very dark activity layer, with a considerable concentration of finds, both ceramics and artifacts, and depositions of animal bones. Seal bones are predominant, often found, more or less, intact, indicating that the area, in some way, was protected from dogs and pigs, during its period of use. Chemical analyses of the soil have shown very high concentrations of seal train, and it is likely that the area served as a ceremonial spot, within the grave field, possibly used for the ritual skinning of seals. Such places, so called *käutaltare*, have been ethnographically recorded on Gotland, as late as the 19th century (Österholm 1997:75-84).

The burials at Ajvide are arranged in two distinctive groups, one with the graves placed in an east-west direction, and one, in a north-south direction. It has been stratigraphically shown, that the graves with an east-west direction, belong to a later phase of use; several of the north-south graves were dug through, in the later phase, but the time-gap, between the two traditions, is apparently very short.

So far, about 2,000 square meters, with a stratigraphic depth of about one meter, have been excavated and documented. All phases, in the documentation and find-handling procedure, have been subject to automatic, computerized treatment, from the project's start in 1983; and, from the 1994 season and onwards, all documentation and registration of finds has been digitalized, using total stations, digital photography, and portable computers, for field registration of data. The find-material consists of more than 20,000 registered artifacts, and more than one million other finds, including about two tons of pottery and about 3.5 tons of

animal bones, mainly seal, pig, fish and fowl. Judging by the computer analyses, extensive systems of more than 300 post-holes, of different size and form, in and around the grave field appear to be the remains of structures, pre-dating the grave-field, as well as sacrificial platforms, houses of the dead, and palisades, that are contemporary with the burials.

Carrowmore, Co. Sligo, Ireland

The Swedish Archaeological Excavations at Carrowmore, 1977-1982 revealed a series of data, that gave possible, alternative explanations, for the appearance of the megalithic tradition in Ireland and Europe, as well as the underlying, settlement-subsistence systems (Burenhult 1980a, 1980b, 1981, 1984, and 1995). The importance of rich marine resources, to the megalith-building population in the Knocknarea area, were strongly emphasized, and domesticated animals probably were introduced at an early stage. The investigation highlighted the complicated, and artificial, boundary between the Mesolithic and the Neolithic periods, suggesting a slow, local, successive transformation, rather than a migration of farmers. The archaeological results were strongly supported by paleoecological studies in the area. The remarkably early dates from the three tombs, that produced datable material (tomb nos. 4, 7 and 27), placed Carrowmore among the earliest megalithic cemeteries in Europe, and thereby, in the world, and stressed the necessity of re-thinking the Irish, megalithic tradition. The earliest date, as yet available from the Carrowmore megalithic cemetery, is from about 5,400 BC (cal) (Tomb No. 4). An overall pattern, concerning the Mesolithic-Neolithic transition, and the appearence of megalithic traditions along the Atlantic coasts of Europe, is emerging from recent excavations, and a series of new questions have arisen. The Carrowmore Megalithic Cemetery forms a central part, in this important process.

In the archaeological survey of Carrowmore, Tomb No. 51, *Listoghil*, holds a central position for several reasons. The monument differs considerably from other tombs within the cemetery, both in size and construction. Its central location, in the middle of the oval-shaped cluster of the other tombs makes it crucial to our understanding of the ritual function and symbolism, of the ritual landscape of the whole cemetery, and its chronological position is, indeed, important in this context. It is the only monument in the cemetery, from which you can see both Ballisadare Bay, to the south, and Sligo Bay, to the north, as well as most of the other Carrowmore tombs. The excavation of Tomb 51 was commenced, during the 1996 season, was continued in 1997, and will be completed in 1998. The chamber, the area around the chamber, and a large segment of the mound are being excavated in order to fulfill three main aims: to provide valid dates, for the construction and use of the monument, to provide a clear picture of the construction of both chamber and mound, that can also be used for a reconstruction of the destroyed, once gigantic mound, and to provide evidence for rituals and ceremonies, performed at this monument. For the same reasons, the burial traditions in this tomb have to be compared to those performed, at the other tombs. Megalithic art has been discovered on the front of the roof slab of the central chamber, and also inside the chamber itself. The more or less intact boulder circle, consisting of about one hundred large stones, has been completely exposed, and thereby,

allows an exact calculation of the monument's original diameter and size. After the 1998 excavation season, Tomb No. 51 will be completely reconstructed. A concrete vault and passage will be built, permitting public access to the central chamber, and the cairn will be restored to its original size.

There is no doubt that the actual position of Tomb No. 51 must have been of major interest in the original layout of the cemetery. This does not, of course, necessarily mean that the dominant chamber, with its cairn, is the first structure to have been built on this focal spot, as the ongoing excavation also has shown. Radiocarbon dates, from the central chamber, have shown that this was built in about 3,600 BC. On the east side of the central chamber, below the intact cairn, three large gneiss boulders were found. The boulders form no part of the chamber. They seem to have been pushed aside, during the chamber construction, and may well be the remains of an earlier megalithic structure, that predates the preserved one.

Hard- and software used for data collection, etc.

As can be seen in the flowchart (fig. 1), a full concept of digital techniques are already used in the field, involving total stations, portable computers, digital photography, and digital drawing. GIS, linked to archaeological databases, including CAD applications, are used to explore relationships, between archaeological and survey data, and between these data and landscape indices. Total station-based topographical maps are produced in *Surfer for Windows*. The files from the totalstation mapping are transferred to lap-tops, via PCMCIA-cards, and preliminary maps are compiled, in the field, to allow for direct visual control of registered landscape features.

Field registration, of archaeological finds and features, is made directly to *MicroStation95*, using customized applications giving non-graphical attributes to graphic objects, with a series of programmed, pre-set forms. These attributes can then be directly exported, to any common database programme. Once registered, the finds appear in their correct position on the screen (in the dgn-file), where different colours are used, for different categories of finds. This allows direct control of position, and also automatically reveals, e.g., distributional patterns of the finds, and other possible relationships, during the actual excavation (Ullén 1997). Also, drawings are made in *MicroStation95*, including 3D-reconstructions of graves and surrounding strata, as well as megalithic tombs (fig. 2).

All finds are successively registered into the database, and are tagged, with detailed information. For graves under excavation, this means that textual data and construction descriptions, as well as find lists, are continuously recorded on the portable computers, during the course of the excavation, with the addition of overview and detail photography, as well as drawings, which are produced and modified in various ways (fig. 3). One great advantage of this method is that find distribution, and tendencies in the appearance of the find material, can be directly identified and studied, during the course of the excavation, and new questions can, thus, be addressed, questions, which ordinarily would have appeared after the end of the excavation, when it

would be too late, to cross-check these new data. This offers the possibility to improve documentation.

The computerized registration, in MicroStation95 and Surfer, means that digital maps can be co-ordinated with satellite and aerial imagery of the region of study, e.g., to confirm concordance, between map and terrain. The coordinates, of the map programmes, can be directly coordinated with those official maps, in digital format, that are available in the respective region. By marking an individual site on the computer screen, the user directly receives detailed, pre-programmed information, in the form of photography, plan drawings, or section, find lists, report text, etc., in the chosen scale/enlargement, and the given coordinates, as well as various kinds of relationships to other registered sites, and their find material within the area of investigation. The database is successively updated, and is thus used, continuously, in the field, during the course of the excavation, including the addition of digital photographs, drawings, and text, and also constitutes the investigation report, directly after the excavation has been completed.

Digital photography

Conventional methods of drawing and photography are the most time-consuming parts of an archaeological investigation, involving long periods of waiting, and resulting in increased costs. The use of digital photography and picture handling, means that most time-consuming activities in investigations, can be all but eliminated, without impairing documentation. In fact, digital methods of documentation, usually involve greater precision in comparison to conventional drawing. Within the Ajvide and Carrowmore projects, digital photography has completely replaced conventional drawing, with regard to the documentation of inhumations, or megalithic tombs, with extensive stone packings.

In the present examples, different, still-video cameras have been used. The most advanced of them, a Minolta RD-175, stores 120 pictures, with high resolution, 410,000 pixels, on the PCMCIA card of the camera. If the computer is connected to the camera (with a cable), the view in question, can be directly studied and adjusted on the screen, before, during, and after the exposure. After the exposure, the pictures can be saved on the computers hard disk, and the pictures, through the camera software, or any photo program, can then be directly adjusted, in different ways, and be supplemented by textual information, e.g., coordinates and levels, (if this has not already been done, at the time of photography), as well as registration of finds, with find numbers or the marking of various features and structures. Layers, stones and other features can be enhanced, with drawn lines, and these can be saved on their own, or together, with the photograph. In the first case, a drawing has, in principle, been completed directly onto the screen, in the field, in the matter of only a few minutes. Maximum objectivity of documentation is reached, if all three pictures are shown together in the report: 1) the original digital photograph, 2) the same photograph, with drawn lines added, and 3) the digitally produced drawing.

The digital picture can be treated in different ways, e.g., transformed, contrasted, lightened or darkened, retouched, or in other ways changed. Depending on the character of the object, this image editing can also manipulate the picture, in order to enhance some or all of its details (e.g., in the form of automatic outline, alternative screen vectorization), that is, the drawing is made directly onto the digital photo on the screen, with the mouse, or via a digitizer. Furthermore, sections of the picture can be separated or removed, be blackened, whitened or turned into a colour, or gray scale.

For the first digital photography experiment in 1994, a well-preserved grave from the Ajvide burial ground was chosen, the individual of which, had been placed in a hocker position. A low resolution camera was used, Dycam. The four images of the skeleton (detail) represent: 1) The digital photograph (vertical) in its original state, 2) a "cleansed" picture, where details which have been considered irrelevant to documentation of the skeleton, have been excluded, 3) a digital "drawing" of the skeleton, created by computer software, and 4) the final vectorization (figs 4:a-d). It should be noted, that the cleansing of the picture, done in step 2, represents the same kind of interpretation, done in conventional drawing work, where naturally occurring smaller stones and gravel are normally not included. The aim of step 2 was to make it easier for the computer programme, to automatically create a useful drawing of the skeleton, without the surrounding, natural structures, which were judged irrelevant to documentation.

The fact that the Carrowmore team is Swedish, has put great demands on efficiency in the field, that is, to make maximum use of the excavation period in Ireland. Early on, this led to the development of a number of different methods, to shorten particularly time-consuming activities, such as drawing, which instead could be done, back in Sweden, by a single person. For instance, in 1979, vertical photo-plans, consisting of a large number of mounted photographs, on Polaroid film, were introduced (Burenhult 1980:a:15-18; 1980:b-66-67). Against this background, the use of digital techniques was a natural development.

The majority of the monumental graves at Carrowmore, consist of a central dolmen or stone cist, surrounded by a stone-circle, built of large boulders, with a diameter of about 10-12 meters. The inner sections, between the central tomb and the stone-circle, consist of massive stone packings, in different layers; and, the drawing of the thousands of stones, in these layers, is one of the most time-consuming activities of the excavation. The measuring, with conventional measuring tapes, is complicated by the fact, that the tombs and their packings are spherical, and every measuring point has to be taken, by using a plummet.

The traditional method of vertical photography with the help of large bi- or tripods, has, at Ajvide and Carrowmore, been replaced by skylift, in order to place photographer and camera at the right angle, about 5 meters above the structure. This means that time-consuming movements, and erections of the tripod, are not necessary; but, above all, unnecessary trampling in the structures, by the team, is avoided. The largest surface possible, that can be photographed in a single digital picture, using a normal lens, is about 4 square meters, and since most structures are considerably more extensive than that, a large number of digital photographs, has to be digitally mounted. For distortion reasons, wide angle lenses

cannot be used. Furthermore, the spheric shape of the stone packings, means that identical height cannot be maintained in all sections, and the outer parts would "lean", more than the inner ones. The great number of pictures, with the following, high degree of overlapping, involves a minimum of distortion. The mounting of the digital photoplan can be done on the screen, in the field. Size adjustment and restitution, to compensate for the leaning surfaces in the plan, can be performed by the software, without difficulty, and the completed plan can serve as a preliminary drawing onto which textual data can be directly added. The time saved is considerable; traditional drawing, in every quadrant, would have taken between two and three days, for each layer. This documentation could now be done in about 2 hours (the time it took to photograph the different sections, save the digital pictures on the hard disk, and add necessary data in written form). Another four hours are needed, for the final mounting, but this work does not disrupt the continued excavation, since all documentation has already been saved (fig. 5).

Telecommunication via GSM

The portable computers used, are equipped with modems for direct communication, over conventional telephone lines, as well as GSM, via mobile phones. This entails several advantages, and rationales, both from a documentational, and security point of view. Data files, faxes and e-mails are sent daily directly from the excavation sites, at Ajvide on Gotland, or Carrowmore, in Ireland, to our stationary headquarters in Visby, or elsewhere in the world. The programmes transmit, very quickly, digital photographs, in colour or black/white, Surfer maps, in colour or black/white, digitally produced drawings, as well as text, via the different telephone networks, including the existing radio- and satellite-born connections, to the receiving computers, and all files are saved automatically on their hard disks. This means double security: in the case of hard disk breakdown in the field, or if the portable equipment is stolen or destroyed. But, the technique has also opened up other possibilities. By communicating directly with laboratories and experts, e.g. osteologists, comments and expert opinions can be obtained on the site, via photography, drawings, textual data – of course supplemented by telephone or e-mail dialogue. Furthermore, databases in the stationary equipment, back home, can be used, even if no personnel is on duty – as with other available databases across the world, which have relevant material, in the form of pictures or text mass. If the receiver is not connected to e-mail, the fax modem of the portable computers can send faxes over GSM, or conventional telephone lines, from the field station hard disk to the receiver's fax, which gets the message or pictures as paper printouts, rather than on the hard disk and screen. Obviously, internet connection is possible, via GSM, in the field, both for incoming and outgoing data; pictures, maps, drawings, text, etc.

During the initial digital fieldwork at Carrowmore, in 1994 and 1995, a series of GSM-transmissions, of different kinds of field data such as text, digital photographs, and maps, in the form of remote mail and fax, were performed, in order to test applicability and security, as well as quality, on the receiving end. Also, equipment for GSM-communication and data transmission, between the different excavation sites, located at distances of up to 3 kilometers in rough terrain were tested. Some of the transferred Surfer colour maps were based on more than three thousand measuring points, and had contour lines, with an equidistance of 1 cm. Our experience of all of the communication above, between Ireland and Sweden, as well as from Gotland, was very good. An ordinary colour photograph took about 20-30 seconds to transmit, without the slightest loss of quality, between the camera objective and the receiver's hard disk. The transmission of complicated colour maps, with comprehensive databases, varied in time (depending on choice of configuration and contour lines), some taking three to seven minutes. No loss of sharpness or exactness, during communication, was noted. It is important to point out, that the handling of the communication equipment, is very simple, and all activities can easily be performed, by participating students, after less than one hour's training in the field.

KARTAGO

The *KARTAGO* software was developed for use, within city or county planning, mainly, where different layers/maps could be combined, and show streets, houses/blocks, telephone lines, electrical lines, water lines, sewage pipes, and so on. It was fully integrated for Windows, networks, or single PC's. The fundamental structure of this GIS system has proved to be ideal, also for archaeological applications, thanks to the exceptional capacity of the program. Extremely large amounts of map-data information can be handled, with no loss of capacity, also when using raster-files, as orthophoto at several hundred Mbytes each. Drawing work is up to one hundred times faster, than within other systems, and this applies to vector-, as well as raster-drawings. The data format is very compact: map data fills between 10% and 30% of other systems, meaning that distribution, netload, and accessibility in portable computers, or the number of CD-roms is optimal.

The presentation quality of graphics is very high, and drawing methods can be accurately adjusted, to allow the screen image, and also a print/plot, to produce the same quality as a printed map. *KARTAGO* can import and export a series of raster formats, as well as vector formats, from *ArcInfo* (Generated Ascii, Ungenerate and GenPlus), *AutoCad* (DXF), *Intergraph*, *MicroStation* (direct from dgn), *AutoKa* (LMV:s transfer file), *MapInfo* (MIF/MID) and several other programs. It provides two-way linking to other Windows applications, e.g., database applications, with GIS links to map objects, and document links, to other types of documents (multimedia). It is easy to create document links with drag&drop, from the file manager. The handling of logic names, guarantees permanent links, even if directory structures should be changed. Also, links to document handling systems, as for example, *DokuLive*, can be made.

KARTAGO can handle up to 1,024 map systems at the same time, where each system may contain many thousands of files, and each map system can have a local grid, and its own drawing method. The map systems can be organized in files, with separate file-indexing for each map system. *KARTAGO* can be used separately, or in combination with other systems, such as *MicroStation*, *AutoCad* and *ArcInfo*, with automatic synchronisation, and can also be used as an archive for maps, that will be shared between many systems. There is

functionality for automatic transformation of map data, between different grid systems, and transformation can be done at import, export, or printing/plotting, without loss of performance. Redlining is also possible.

Within the Ajvide and Carrowmore projects, *KARTAGO* is used mainly for education, presentation and visualization. At the Historical Museum of Gotland, in Visby, the Ajvide exhibition includes three computer monitors, that can be used interactively, presenting the different aspects of digital techniques. The first monitor presents KARTAGO, with a series of different layers and zoom options available, for the visitor: the digital aerial orthophoto of Eksta parish; the digital economic map of Eksta parish; the digital Register of National Monuments in Sweden, Eksta parish; the digital (total station-based) landscape reconstruction; and the (totalstation-based) excavation plan, drawn in MicroStation95, of the Ajvide settlement and burial ground, including graves and finds (figs 3; 6:a-b). Zoom options run from full scale view of the parish, down to a single find on the site. Zoom ratio automatically guides what kind of information is available on the screen. For example, the actual excavation area is too small to be visible from the higher levels of view, and consequently, automatically appears at a certain level.

Different coastlines from various periods, in connection with the occupation, can be chosen by level, showing the gradual move of the prehistoric activity area (figs 7:a-c). A series of hypertext links are also available, including aerial and excavation photographs, text information from the register of National Monuments, finds, osteological information on the skeletal material, etc. The links are activated, by placing the mouse pointer on the actual document.

The second monitor shows the excavated area (MicroStation95) with all finds and graves, again with zoom options, down to a single vertebra, of one of the skeletons. The third monitor is constantly linked to the Internet, where the Ajvide home page is up-dated every day, directly from the excavation, using digital cameras and GSM-transmissions of pictures and files.

At Carrowmore, KARTAGO will be used in much the same way, at the planned, new Carrowmore Visitor's Centre, due to open in the year 2,000. Special features here are 3-D reconstructions of the tombs, a reconstruction of the megalithic cemetery, as it was documented in the 1900s, before the destruction of more than half of the then known tombs. The visitors can change the angle of view, of the different tombs, by changing the perspective, e.g., by chosing fly-by film sequences. Sections and plans can be chosen as hypertext links, and detailed information on finds, also photographs, can be obtained by clicking on the document, which is a symbol of the find itself. Hypermedia links, showing actual excavation situations, will be available.

Acknowledgements

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List of Figures in CD-ROM.

c: The same photograph automatically contrasted in the field situation, in order to create a field drawing for text and other data registration.

d: The final vector drawing of Grave n°. 36.

Fig.5. Digital photo-mount of one of the quadrants of Tomb n°. 56 at Carrowmore. The mount consists of 26 vertical photographs.

Fig.6:a-c.

Map of section of Eksta parish, Gotland, in three different scales, shown with KARTAGO Geographic Information Systems (GIS). This GIS application is a simple and fast way to simultaneously display various combinations of geographic database information. The images show the following levels: the digital aerial ortophoto of Eksta parish; the digital economic map of Eksta parish; the digital register of National Monuments in Sweden, Eksta parish; and the totalstation-based excavation plan of the Ajvide settlement and burial ground. Map compiled by Digpro AB, Stockholm. Distribution approved by the National Land Survey of Sweden.

Fig. 7:a-c.

The Ajvide topography, based onthe totalstation mapping, showing the landscape at three different stages of occupation, as displayed in KARTAGO. Contour lines: 0'25 m. Maps produced in Surfer for Windows.

a: The Ajvide shoreline at c. 2950 BC. The coastline of that time is situated 12 meters above the present, which in the stratigraphy corresponds to today's 12,5 meter contour line. Excavated area is marked.

b: The coastline around Ajvide at c. 2300 BC, the final phase of the burial ground.

c: The coastline around Ajvide at c. 1800 BC, the Early Bonze Age.