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THE FUTURE OF OUR PAST '93-'95

BUDAPEST

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The Future of Our Past '93–'95

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Editor in Chief István Gedai

Edited by Erzsébet Marton

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Contents

Editorial 5
Program '93 6
Program '95 7
Gary Lock: An introduction to Geographic Information Systems (GIS) and archaeology 8
Sebastian Rahtz: Archaeology and computer culture 26
Paul Reilly: Access to Insights: stimulating archaeological visualisation in the 1990s 38
Andrea Vaday–Ildikó Fejes: Data analyses and interpretations based on information content in practical and theoretical archaeology 52
István Zalai-Gaál: Hierarchical typological systems as a basis of computer analyses 53
Attila Suhajda: Seriation and its Application in Archeological Research 54
Tamás Bezeczky: Documentation and description method of Roman amphorae, typological analyses with the application of mathematical statistics 60
Gábor Rezi Kató: Computer project of the Hungarian National Museum 1982-1993 72
Ferenc Springer: The Information Infrastructure Program (IIF) for Research, Development and Higher Education (1986-1993) 79
Gyula Engloner–Attila Suhajda–Katalin T. Biró: Theses for the informatical development of the museums 80
Ferenc Redő: Excavation documentation of Alsórajk–Kastélydomb in GIS system 82
Ferenc Gyulai: A new interdisciplinary workshop, the 'Archaeological High-Tech Centre' 83
Attila L. Tóth: Scanning Electron Microscope as Multidimensional Input Source of Image Analysis 85
Katalin Barlai–Ida Bognár-Kutzián:The Role of the Sun in the Ritual of the Copper Age Burials in the Carpathian Basin 87
László Bartosiewicz–Wim Van Neer–An Lentacker & Bea De Cupere: Measurement of bone mineral content in archaeozoology 88
Katalin T. Biró: The application of computers in the study of the lithic raw material exploitation sites at Szentgál-Tűzköveshegy and the related workshop complexes 90
László Domboróczki: A possible model of database organisation for computerised archaeological excavations 94
Ottó Sosztarits–Zsolt Vízvári: Computer registration of excavation evidence at Szombathely – Fő tér 97
István Torma: StaTOR Information Sheet 98
Katalin Szentirmai: The data management system of the Museum of Aquincum 99
Zsuzsa Tószegi: Visual information 102
László Z. Karvalics: From the information technology boom till social changes: archaeology, as an example 103
Ferenc Redő: Documentation and simulation of a Roman imperial villa in Central Italy 104
József Harangozó–Erzsébet Marton–Gyula Nováki: A special method of measuring for the topometry: A software developed by György Sándorfi 105

Ida Bognár-Kutzián–Katalin Barlai: Was the "look" of the dead or the position of the body decisive in the burial rite in the late neolithic age? 109
Gábor Rezi Kató–László Újlaki: Algorythmic data analysis in archaeological research 110
Andrea Vaday–András Grynaeus: Dendrochronological study of the Roman wells found during the rescue excavations of the Ménfőcsanak-83 road 115
Ferenc Gyulai: Image analytical analyses in the Archaeological Technical Centre of the National Science Foundation Project 124
Gyula Munkácsy: Exhibition - photo - computer - restoration of the content of archive phogographs 125
Katalin T. Biró: Pictures of an Exhibition 130
Zsófia Medzihradszky: Archeobotanical and Holocene palynological database 135
Attila Suhajda: The BASE Graphical Artifact Inventory and the THEO Terminology Classification Systems 136
Zoltán Czajlik–Balázs Holl: Archaeological Chronology and Excavation Data Bases 144

THE FUTURE OF OUR PAST '93–'95

Two National Conferences on the Application of Computers and Information Technology in Archaeology and other fields of Museum Research

Editorial

The Future of Our Past Conference series was organised following the tradition of the series of conferences organised in Great Britain entitled Computer Applications in Archaeology. This annual series essentially furthered the subject in the UK. There were also Hungarian antecedents of our Conference: in 1991, the first meeting under this title was organised in the Hungarian National Museum. After several minor meetings on the advance of computer sciences in the field of museum informatics, the Future of Our Past series seem to acquire considerable regularity. Both of these meetings attracted interest of the profession. Abstracts of the meetings were published for the conference, but the full text of the papers could not be published with the same speed and energy. This is partly due to economic difficulties in printing a monograph, but also difficulties in 'dragging' manuscripts from certain contributors. Finally, we decided to publish the available material in one volume.

In a fast developing field, this enterprise may seem dangerous. At the same time, the pioneering ideas expressed in 1993 deserve due attention even today. In case of some ongoing projects, the course of development from plan to 'perfection' seems also interesting. The dynamically development of information sciences cannot avoid the museum field as well. More and more archaeologists and museologists use computers in their everyday work. By this series we want to establish a regular forum for getting acquainted with each others work as well as results of international research. We would like to express our thanks to the Hungarian National Museum offering home to the meeting and a number of firms and other institutions supporting the organisation of the Conference.

Invited speakers of the Conference (1993):

Gary Lock
Institute of Archaeology, Oxford University
Paul Reilly
IBM UK Laboratories Ltd.
Sebastian Rahtz
ArchaeoInformatica, York

Invited speakers of the Conference (1995):

Ferenc Telbisz
ELTE Institute of Informatics
Zsuzsa Tószegi
National Széchényi Library
István Moldován
Hungarian Electronic Library
László Karvalics
University of Polytechnics

PROGRAM '93

Thursday, 13th of May 1993

10.00 Conference Opening
10.30 Gary Lock: Geographic Information Systems (GIS) and archaeology (45 p.)
11.20 Sebastian Rahtz: Archaeology and computer culture (30 p.)
11.55 Paul Reilly: See the Unseen: advanced visualisation for archaeologist in the 1990s (30 p.)
14.00 Andrea Vaday–Ildikó Fejes: Data analyses and interpretations based on information content in practical and theoretical archaeology
14.25 István Gaál: Hierarchical typological systems as a basis off computer analysis
14.50 Attila Suhajda: Theory of seriation and possibilities of its application
15.15 Tamás Bezeczky–Pál Kerékfy: Documentation and description of Roman Amphorae; typological studies using mathematical statistics
16.10 Gábor Rezi Kató: Computer programs of the Hungarian National Museum 198–21993
16.35 Ferenc Springer: Information Infrastructure Program (IIF) for Research, Development and Higher Education (1986–1993)
17.00 Gyula Engloner–Attila Suhajda–Katalin T. Biró: Theses for the informatical development of the museums

Friday, 14th of May 1993

9.30 Ferenc Redő: Excavation documentation of Alsórajk–Kastélydomb in GIS system
9.55 Erzsébet Jerem: Archaeological topography of Sopron environs in GIS
10.20 Ferenc Gyulai: A new interdisciplinary workshop, the 'Archaeological High-Tech Centre'
10.45 Attila Tóth: Scanning Electron Microscope as Multi-dimensional Input Source of Image Analysis
11.30 László Töll et al.: Computer modelling of Medieval cross-bows
11.55 Katalin Barlay–Ida Bognár–Kutzián: The role of the sun in the ritual of the Copper Age Burials in the Carpathian Basin
12.20 László Bartosiewicz et al.: Measurement of bone mineral content in archaeozoology
12.45 Katalin T. Biró: Computer applications in the study of the Szentgál–Tűzköveshegy mine and workshop complexes
14.30 László Domboróczki: A possible model of database organisation for computerised archaeological excavations
14.55 Ottó Sosztarics–Zsolt Vízvári: Computer registration of excavation evidence at Szombathely – Fő tér
15.20 László Langer (IQ-Soft): Oracle Libraries: features and applications (15 p.)
15.35 Imre Molnár (VT-Soft): INGRES RDBM: features and applications (15 p.)
15.50 István Torma: StaTOR 1.3/H Information Sheet (15 p.)
16.05 László Újlaki (Aktív Rekord Bt): Gerenia Neuron Network: developing system and applications (15 p.)

16.20 Database presentations

– Katalin Wollák: Archaeological protected areas

– Emil Ráduly: Computer assisted data management in the Open Air Ethnographic Museum

– Katalin Szentirmai: The data management system of the Museum of Aquincum

16.50 Closing Address

PROGRAM '95

Thursday, 18th of May 1995

10.00 Conference Opening: Ferenc Szikossy, dr. (Hungarian National Museum)

10.50 Zsuzsa Tószegi: Visual information

11.20 László Z. Karvalics: From the informaton technology boom till social changes: archaeology, as an example

13.15 Ferenc Redő: Documentation and simulation of a Roman imperial villa in Central Italy

13.40 József Harangozó–Erzsébet Marton–Gyula Nováki: A special method of measuring for the topometry: A software developed by György Sándorfi

14.00 Presentations

Friday, 19th of May 1995

9.00 Katalin Barlai - Ida Bognár-Kutzián: Was the "look" of the dead or the position of the body decisive in the burial rite in the late neolithic age?

9.25 Gábor Rezi-Kató - László Ujlaki: Algorythmic data analysis in archaeological research

9.50 András Grynaeus-Andrea Vaday: Dendrochronological study of the Roman wells found during the rescue excavations of the Ménfőcsanak–83 road

10.15 Ferenc Gyulai: Image analytical analyses in the Archaeological Technical Centre of the National Science Foundation Project

12.00 Gyula Munkácsy: Exhibition - photo - computer - restoration of the content of archive photographs

12.25 Katalin T. Biró: Pictures of an Exhibition

14.15 Zsófia Medzihradszky: Archaeobotanical and Holocene palynological database

14.40 Attila Suhajda: THEO

15.10 Zoltán Czajlik–Balázs Holl: Archaeological dating and site databases - presenting the 'ages-structure'

16.00 Discussions

An introduction to Geographic Information Systems in Archaeology

Dr . Gary Lock
Institute of Archaeology, Oxford University
36, Beaumont Street, Oxford OX1 2PG, UK

ABSTRACT

The use of GIS in archaeology has had considerable exposure over the last couple of years. This paper will examine the reasons why GIS technology is so appealing to archaeologists and look at the main areas of application to date. It will also raise some issues of archaeological theory and practice that GIS are offering new insights into: are GIS just a passive tool or are they capable of generating new theoretical approaches? The use of GIS for Cultural Resource Management (CRM) will be discussed with reference to the prototype GIS-based Oxfordshire Sites and Monuments Record. Currant issues such as CRM databases as research tools and the concept of corporate databases will be raised. The second case-study will be the use of GIS to analyse the landscape around the later prehistoric hillfort of Danebury in central southern England. Approaches to spatial analysis within this changing archaeological landscape will be demonstrated showing how GIS can build on existing theoretical frameworks. Finally, a few words of warning concerning the use of GIS will be given. Despite its appeal, this technology is limited within some aspects of archaeological requirements.

1. Background: why are GIS interesting to archaeologists?

It is a simplistic truism to state that spatial information and spatial analysis have always been important within archaeology. Past human activity has resulted in a complex web of sites and artefacts all of which have a spatial component and spatial relations. Archaeologists attempt to decipher these data using a variety of methods and techniques. For spatial data the traditional approach is through the use of maps, plans and, more recently, spatial statistical methods. The two main conceptual axes of archaeology are time and space and the major concerns within the discipline are centred around identifying patterns along one or both of these axes. Whether working at the inter-site scale with plans of excavation areas or at the regional and continental level with distribution maps, the graphical representation of the spatial relationships of data has always been a fundamental tool of the archaeologist. The results of a British Government Committee of Inquire into the handling of spatial data were published in 1987 under the chairmanship of the geographer Lord Chorley. In it he wrote that the development of GIS was 'the biggest step forward in the handling of geographic information since the invention of the map' (DOE 1987, p.8). With such a claim being made for GIS technology it is hardly surprising that over the last few years the number of archaeological applications has grown rapidly.

The connection between archaeology, maps and GIS made in the opening paragraph is a fairly obvious one. It is also possible to identify three general themes within the development of archaeology which have added to the current attraction of GIS for archaeologists. The first of these is the increasing importance of the concepts and methods of landscape archaeology. This involves the study and reconstruction of complete past landscapes and places the emphasis on the relationships between sites and between sites and their environment rather than on individual sites as 'islands' within a landscape. This approach has a long tradition, certainly in England, where the 17th and 18th Century antiquarians John Aubrey and William Stukeley were observing and recording prehistoric monuments within their landscape settings. It was the latter who commented on the fact that the round barrows around Stonehenge were located on false ridges rather than on hilltops. In 1953, O.G.S. Crawford, the pioneer of modern landscape archaeology made the following observation:

"The surface of England is a palimpsest, a document that has been written on and erased over and over again and it is the job of the field archaeologist to decipher it." (Crawford, 1953, p51).

Both the spatial relations noted by Stukeley and the deconstruction of the complexity of the landscape suggested by Crawford are ideal GIS applications and show the long tradition of archaeological theory existing to accommodate the technology.

The second theme is the increasing interdisciplinary approach of landscape archaeology and the borrowing of methods and techniques from other subject areas, especially geography. The use of techniques such as Thiessen Polygons and Central Place Theory (Grant 1986), Site Catchment Analysis (Vita-Finzi and Higgs 1970) and the theory and concepts of Cultural Ecology (Butzer 1982) have enriched the approaches of archaeologists to the study of past landscapes. The employment of GIS can be seen as the latest element within a long and close relationship between archaeology and geography involving the adoption and adaptation of many theoretical approaches and methodologies (Goudie 1987).

The third important theme is the increasing use of computers and quantitative methods within archaeology. This can be traced back to the so-called New Archaeology of the 1960s and 1970s and the Quantitative Revolution that took place in many disciplines at that time including archaeology and geography. An integral part of these new methods were a whole series of spatial statistical techniques, again many of them borrowed and adapted from other disciplines (Hodder and Orton 1976). Because all of these methods deal only with point and/or grid distributions and the aim of producing a probability value for some variation of deviation from randomness (see, for example the papers in Hietala 1984) there is now a general disillusionment with the usefulness of spatial statistics for many archaeological situations. The inability to include background information makes the analysis of point distributions very rigid and reductionism and the resulting probabilities are often difficult to justify in archaeological terms. The time is right for new computer-based approaches to spatial analysis which can incorporate the whole range of spatial information and not reduce it to a series of points. So, to summarise, the attraction of GIS is that they are map-based, they can include data on the total environment in which archaeology occurs and they are analytical and not just passive.

2. GIS technology

GIS is a generic term which covers many different software packages running on many different types of computers. It is, however, possible to identify core elements that comprise GIS technology. In one of the earliest, and best, text books on the subject (Burrough 1986) the following definition was offered and it is still difficult to improve upon: 'GIS are a set of tools for collecting, retrieving at will, transforming, and displaying spatial data from the real world'. A GIS application consists of a spatial database which stores spatial data in the form of maps which are linked to attribute data within a standard relational database. *The real power of GIS is in their analytical capabilities allowing data to be accessed in different ways:*

- according to their position with respect to a known co-ordinate system (e.g. all archaeological sites within specified grid references)
- according to attributes that are unrelated to position (e.g. all archaeological sites that have been excavated since 1950)
- according to their spatial interrelations with each other (topological relations) (e.g. all archaeological sites within 2 km of a river)
- according to any combination of the above. This allows very complex retrievals (e.g. all Iron Age hillforts above 1,000 m altitude that are within 1km of a river, have been excavated and are within specified grid references).

Data structure and data storage within a GIS are fundamental to the types of analysis that can be performed. The two important data structures are raster and vector and most GIS packages tend to be primarily one or the other although more recent systems do allow transfer between the two structures. In simplistic terms a raster structure imposes a grid of pixels over the area of interest and each pixel has a value assigned to it reflecting the data value at that point. A vector system stores points as co-ordinates which can be joined to form lines and polygons, Figure 1 shows these three spatial primitives. Data elements, whether point, line, polygon, pixel or group of pixels can have numeric or alphanumeric attribute data attached to them. In archaeological terms, a small site represented by a point or a large site defined by a polygon can have any sort of attribute information attached to it in the database. This could include Cultural Resource Management data such as ownership and condition monitoring or more research type information, excavation finds for example.

The spatial database is built using the concept of layers (or coverages) as illustrated in Figure 2. Each coverage is georeferenced by matching grid points and each contains data representing a single category of information. This allows, and encourages, the combination of topographical, environmental, modern and archaeological data. A powerful and important function available within GIS is the generation of new data coverage from existing ones. For example, for every point in the geographical area represented, aspect and slope can be generated and saved as two new coverage using data in the existing relief (contours) coverage. A new coverage recording the distance from surface water for every point in the study area could be generated from the hydrology coverage and then used in future analyses. A concept of fundamental importance within GIS and one which relates the data within each coverage and between coverage is that of topology. This creates an integrated spatial database from individual coverage within which spatial relations between all data elements are known.

A GIS spatial database is expandable by the addition of new coverages. Raster coverages can be captured by scanning and vector data either by digitising or purchasing map data in a digital form, attribute data are entered into the database as for a standard database. Within many modern systems raster and vector coverage can be used at the same time. For example, vector data can be overlain on scanned aerial photographs, satellite images, or geophysical survey data both of which are stored as raster coverages. Horizontal expansion is attained by georeferencing new map sheets to form a seamless map extent within the system (Figure 3). This enables zooming in and out and an area of interest to be windowed for retrieval and analysis.

3. Archaeological analysis and GIS

The section above gives only a brief introduction to some technological aspects of GIS. There is a burgeoning literature covering the theory, concepts, technology and applications of GIS and the interested reader requiring basic information is pointed towards the following texts; Burrough, 1986; Maguire et al, 1991; Star and Estes, 1990. Applications in archaeology are given full coverage in Allen et al (1990) and Lock and Stancic(1995) with a useful overview in Kvamme (1989). Kvamme (1992) and Lock and Harris (Forthcoming) also synthesise and demonstrate the analytical capabilities of GIS as applied to archaeological data.

Probably the most interesting aspect of GIS to archaeologists are their functionality and analytical capabilities. GIS are not just digital mapping software attached to a database despite the fact that some digital mapping products are (deceptively?) marketed as GIS. GIS are driven by an analytical engine that enables a whole range of data manipulation techniques and analyses based on the topological relations of data elements resulting in either graphical and/or statistical output. An important concept in this context is that of data visualisation: the ability to explore and view complex spatial data sets from a variety of different angles. An approximate parallel to this approach (although much more rigorously defined) is the methodology of statistical Exploratory Data Analysis whereby patterns within the data are teased out by an iterative process involving reworking the same data over and again with the emphasis on visualisation rather than confirmatory statistics.

Within this short paper it is only possible to briefly illustrate some of the main areas of analysis rather than the whole range of analytical techniques available in GIS. Because of data organisation based on coverage, the ability to overlay and reclassify using map algebra is important. Any number of coverages can be overlain and viewed either as 2-dimensional maps or as pseudo 3-dimensional DTMs generated from contour data (Digital Terrain Models which are strictly 2.5-dimensional). With archaeological data organised by period coverage it is possible to disagregate complex cultural landscapes and view them a period at a time, to move towards the decipherment called for in Crawford's quote above. DTMs with any number of data coverages draped over them, are a powerful visualisation tool enabling archaeological data to be viewed from a range of directions and heights. This can often produce new insights into spatial relationships between archaeological data, environmental data and location within a landscape. New coverages can be generated, saved and used such as aspect, slope and 'distance from' as mentioned above together with new coverages reclassified from existing ones. For example, two coverage which are classified, one according to distance from water and the other by altitude could be combined to produce a third showing a new class of land that is both above a certain altitude and within a set distance from water.

Figures 4 and 5 illustrate some of the points made above using data from a prototype GIS-based Sites and Monuments Record for a part of Oxfordshire in England (Harris and Lock 1992). Figure 4 shows a DTM which has been generated from contours (unfortunately this part of Oxford shire is very flat!) with archaeological sites draped over the model and classified according to type of site. The key is based on coded data stored within the attribute database so that the same data could be colour coded and displayed according to other attributes that are stored such as 'period'. It is important to emphasis here that Figures 4 to 10 in this paper are monochrome versions of colour screen images and lose an important aspect of visualisation which is the use of colour. Another point worth making is the interactivity of some GIS software; the direction and height of view of the DTM are user-defined and can be quickly changed to generate new views.

Analyses based on the concept of buffering are proving to be of great interest in archaeology. Within vector systems any point line or polygon can have a buffer of specified size placed around it, as can any group of pixels within a raster-based system. Once a buffer or set of buffers are defined, data from other coverages occurring just within the buffers can be analysed. Figure 5 shows a Cultural Resource Management application of buffering whereby the impact of a road widening scheme on the local archaeology is being assessed. The 2-dimensional map shows the road and soil coverage overlain with a 100m buffer generated around the road to be widened. Within the buffer is displayed archaeological sites categorised by type of site. For each site shown the attribute data from the database can be listed to aid the planning engineer in decision making and assessing the impact of the proposed scheme.

Closely related to buffering is the archaeological technique of Site Catchment Analysis. All of the following figures are taken from a study of the later prehistoric landscape around Danebury Iron Age hillfort in central southern England (Lock and Harris Forthcoming). Figure 6 shows a small part of the study area centred of Figsbury hill fort and using a DTM to illustrate its dominant position overlooking the valley. A total of six coverages are draped over the DTM showing small farmstead settlements, field systems and linear ditch systems thought to be contemporary with Figsbury together with rivers and soils which are mainly in the valley bottom. One of the interesting research aspects concerning this period are the social and economic relationships between the farmsteads and hillforts and between the farmsteads themselves. Models of landscape use involve ideas of territoriality based on individual hillforts and private and communal ownership and use of land by farms. In Figure 7. each of the farmsteads is surrounded by a 400 m and 1,000 m radius buffer to represent infields for private use and outfields with shared communal pasture. A variation on this theme in which different soil types within buffers are analysed is presented by Gaffney and Stancic (1991 and 1992) using the island of Hvar, Slovenia as a case study. They demonstrate a relationship between certain types of sites and high quality agricultural land and show the statistical capabilities of GIS in testing the significance of such relationships by using the Chi-squared test. The Gaffney and Stancic work is also important in showing the use of cost surface analysis to modify the size and shape of buffers according to the ease of movement across the landscape. This makes the resulting model much more realistic in terms of ancient land use by discounting non-arable land on steep slopes.

Another powerful analytical function of GIS, based on the properties inherent within DTMs, is the ability to generate viewsheds and perform line-of-sight analyses. A viewshed is the area of landscape visible from a given point on or above ground surface, as in Figure 8 which shows the viewshed from Figsbury and emphasises its dominant strategic position overlooking the valley and contemporary farmsteads. A line-of-sight analysis is a simple sub-set of this whereby visibility between two specified points on the landscape is either verified or not. Figures 9 and 10 show the distribution of Neolithic long barrows in the Danebury study area (Lock and Harris Forthcoming). Existing archaeological theory concerning these monuments involves ideas of them being territorial markers with each one being a visually prominent symbol of a particular social group's spatial domain. A long established technique in archaeology for testing such spatial relationships is the use of

Theissen Polygons which can also be generated within GIS as shown in Figure 9. It is interesting to note that in several cases a long barrow occurs in a high position looking out over its 'territory' as defined by the polygon and this could be used to support the visual symbol theory. This illustrates yet again the visualisation power of the DTM in showing 3-dimensional spatial relationships that would not be so obvious from a 2-dimensional map with contours.

Returning to viewsheds, it is possible to use them for a different approach to testing the theories concerning long barrows. Whether or not a barrow is visually dominant within its landscape is indicated by the extent of its viewshed which not only shows the land visible from the barrow but also the reverse; the area of land which the barrow is visible from. A comparison of viewsheds and Theissen Polygons for all barrows in the Danebury study area showed that many of them are not situated to be visually dominant and some of them, in fact, have peculiarly restricted views. An interesting aside which became clear during this analysis is that all of the barrows appear to be positioned to achieve mutual non-intervisibilty, see Figure 10. From any one barrow none of the others are visible to the extent that the boundaries of several viewsheds snake around other barrows positioning them just out of view. Again this is the power of visualisation working and the ability of GIS to influence archaeological theory rather than just perform as a passive, atheoretical tool.

4. The future for GIS in archaeology?

Despite the obvious importance of GIS to archaeological work demonstrated above and described more fully in many of the references cited, there are serious problems which are acting as inhibitors to the adoption and adaptation of GIS technology in archaeology (Harris and Lock 1990). For larger applications, likely to be institutional and concerned with Cultural Resource Management, there are significant financial commitments for hardware and software considering the usual position of under-funding in which archaeology finds itself. Smaller-scale PC-based GIS which are less expensive may be adequate for personal research applications but are unlikely to be able to process the large data files associated with regional or national sites and monuments databases. Training is another important issue to be faced, again especially for large institutional applications where many users may be sharing a corporate GIS database. GIS are not simple software to use even if the existing workforce is highly computer-literate to start with.

It has been demonstrated over and again that a large proportion of any GIS application budget, 80% to 85% in many cases, is used on data acquisition. Obtaining the essential digital map base for an application can be a major commitment of time, effort and money which needs to be fully thought through at the planning stage of the project. The availability of digital data varies between countries, being freely available in some, available at considerable cost in others and not available at all elsewhere. The alternative to acquiring digital map data is the daunting task of digitising the map base and the associated task of identifying and editing errors. The acquisition of attribute data can also be complicated by the very specific requirements of GIS data structures. The existence of attribute data within a standard database does not ease the situation because the spatial referencing of GIS data is incompatible with the usual method of recording spatial data within a database record. The idea that a GIS can be simply attached as a front-end to an existing database is a dangerous misconception that seems to be prevalent particularly in the area of Cultural Resource Management where large databases already exist.

Despite these drawbacks it is guaranteed that GIS applications in archaeology will multiply considerably over the next few years. In the commercial world GIS are a multi-million dollar industry which will continue producing improved software that fringe users such as archaeologists will benefit from. The history of computer applications in archaeology shows that archaeologists are adept at using specialist commercial software to satisfy their very particular needs. The functionality and power of GIS are such that they become more than just passive tools and are able to influence the generation of archaeological theory, model building and new ways of exploring spatial data. It is this added dimension which makes GIS and their future use in archaeology so exciting.

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Figure captions

Figure 1. The three data primitives of point, line and polygon as used in vector data structures.

Figure 2. The concept of data layers (or coverages) as used in GIS. New layers such as slope and aspect can be generated, stored and used in analyses. Topology is the spatial relations between data elements on different coverages and is fundamental to GIS functionality.

Figure 3. Spatial data which are input as individual map sheets are stored as a seamless map extent within GIS. Any area can be defined for analysis.

Figure 4. Cultural Resource Management with GIS - the prototype Oxfordshire Sites and Monuments Record showing archaeology classified by type of site draped over a DTM.

Figure 5. The same area as Figure 4 shown as a 2-dimensional map with roads and soil coverages overlain. One road has a 100 m buffer generated around it and archaeological sites classified by type of site are shown within the buffer illustrating the impact of a possible road widening scheme.

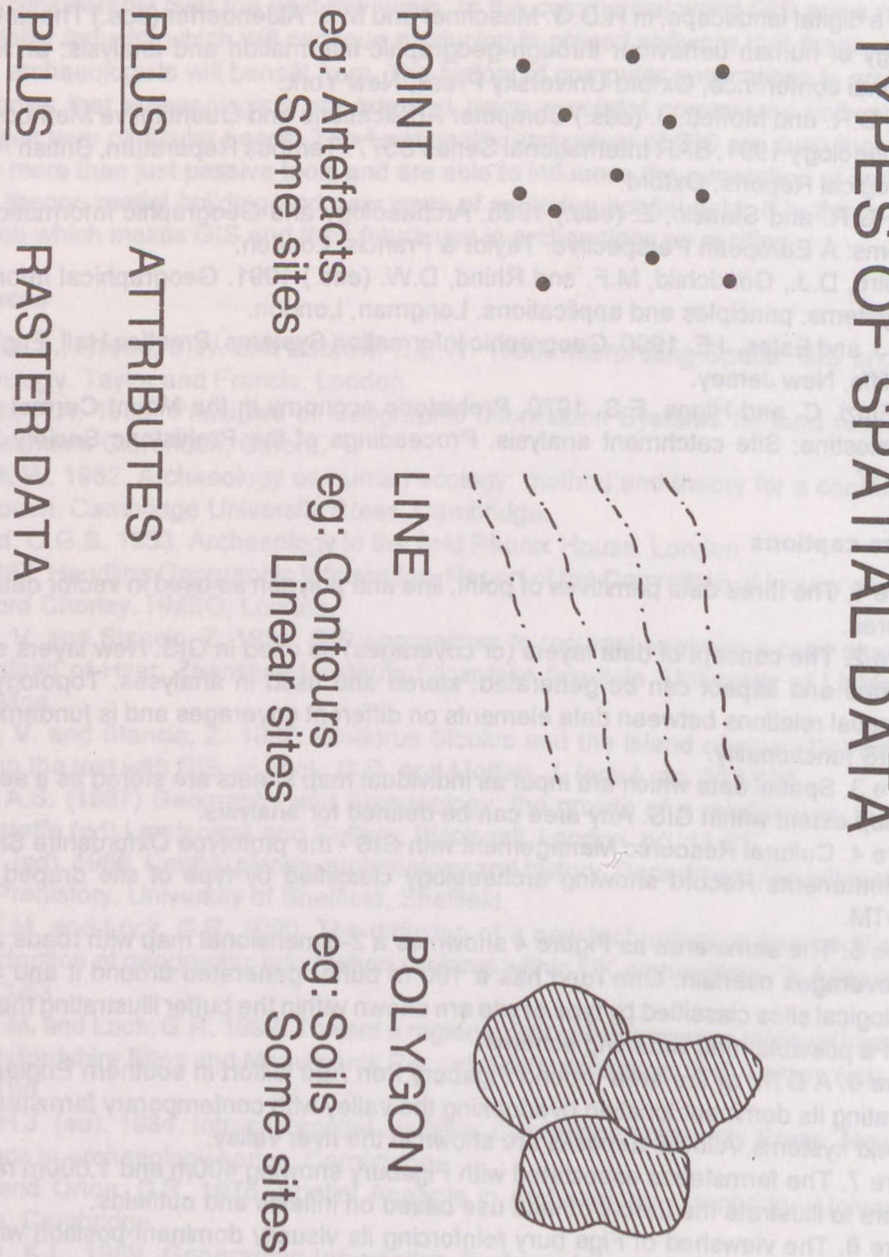
Figure 6. A DTM of the area around Figsbury Iron Age hillfort in southern England illustrating its dominant location overlooking the valley with contemporary farmsteads and field systems. Alluvial deposits are shown in the river valley.

Figure 7. The farmsteads associated with Figsbury showing 400m and 1,000m radii buffers to illustrate the theory of land use based on infields and outfields.

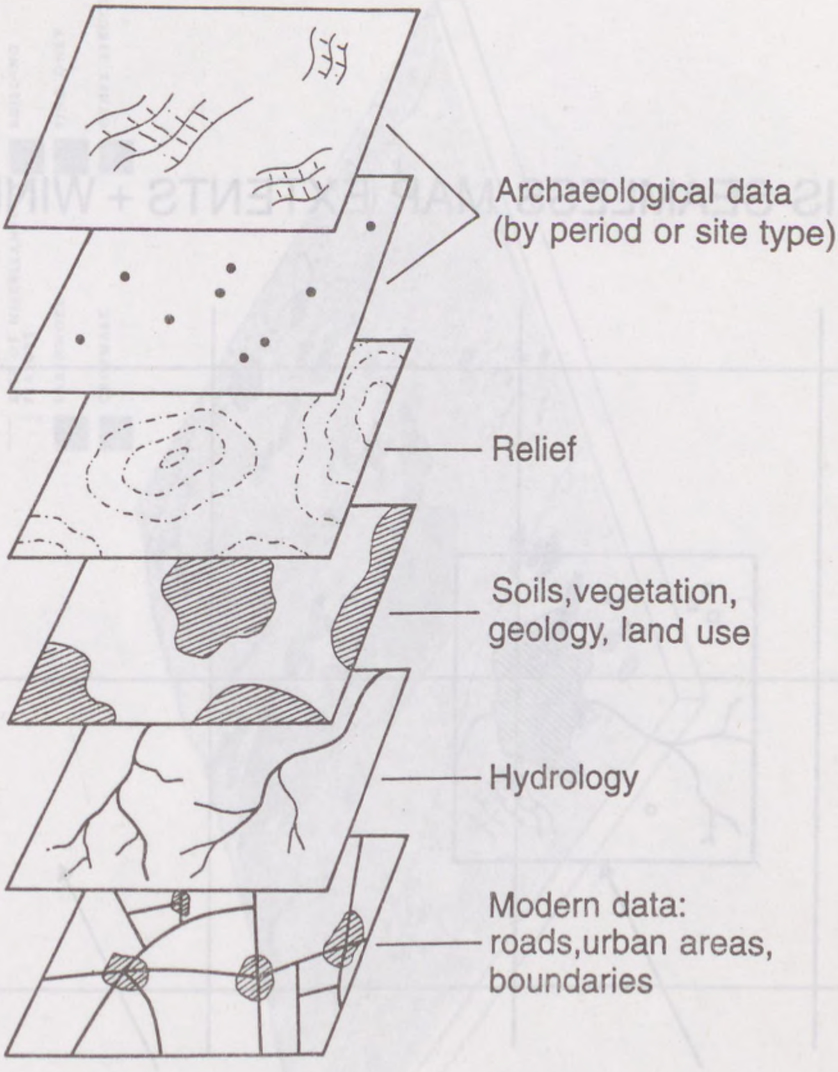
Figure 8. The viewshed of Figs bury reinforcing its visually dominant position within the landscape.

Figure 9. Neolithic long barrows in the Danebury study area with selected viewsheds and Thiessen Polygons to illustrate the theory of territoriality.

Figure 10. The same long barrows as in Figure 9 with viewshed illustrate non-inter visibility between barrows.


TYPES OF SPATIAL DATA
POINT
eg: Artefacts
Some sites
LINE
eg: Contours
Linear sites
POLYGON
eg: Soils
Some sites
PLUS ATTRIBUTES
PLUS RASTER DATA

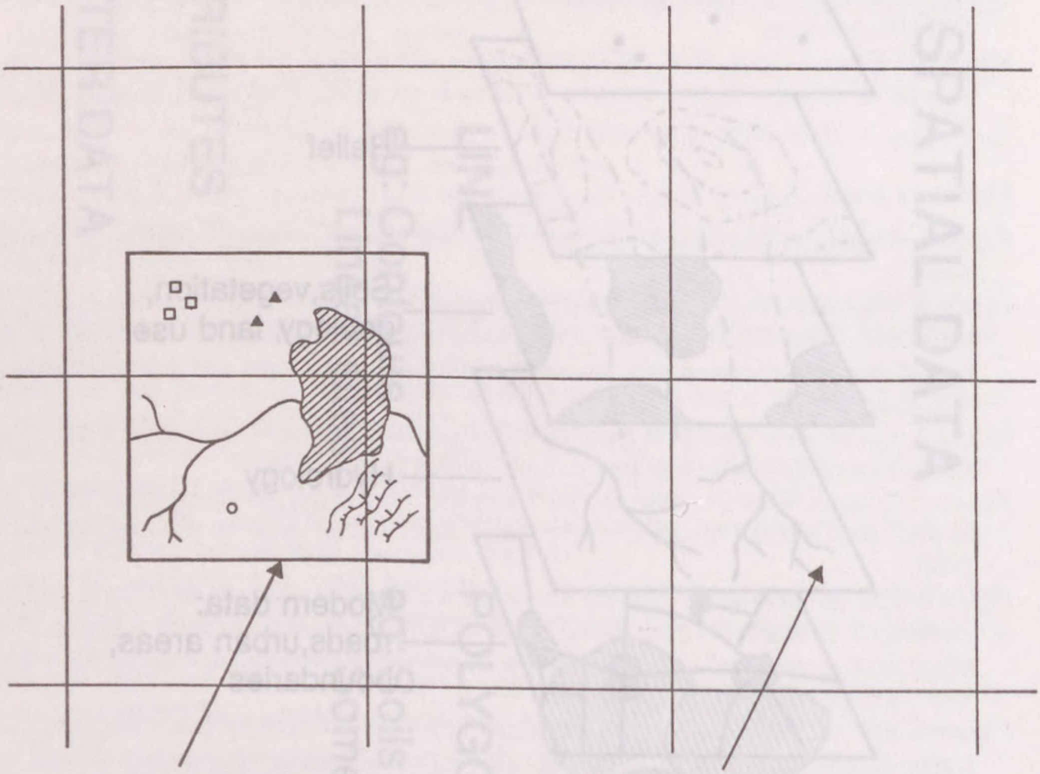
(GIS) GEOGRAPHIC INFORMATION SYSTEMS



New layers: Aspect
Slope
Distance from water

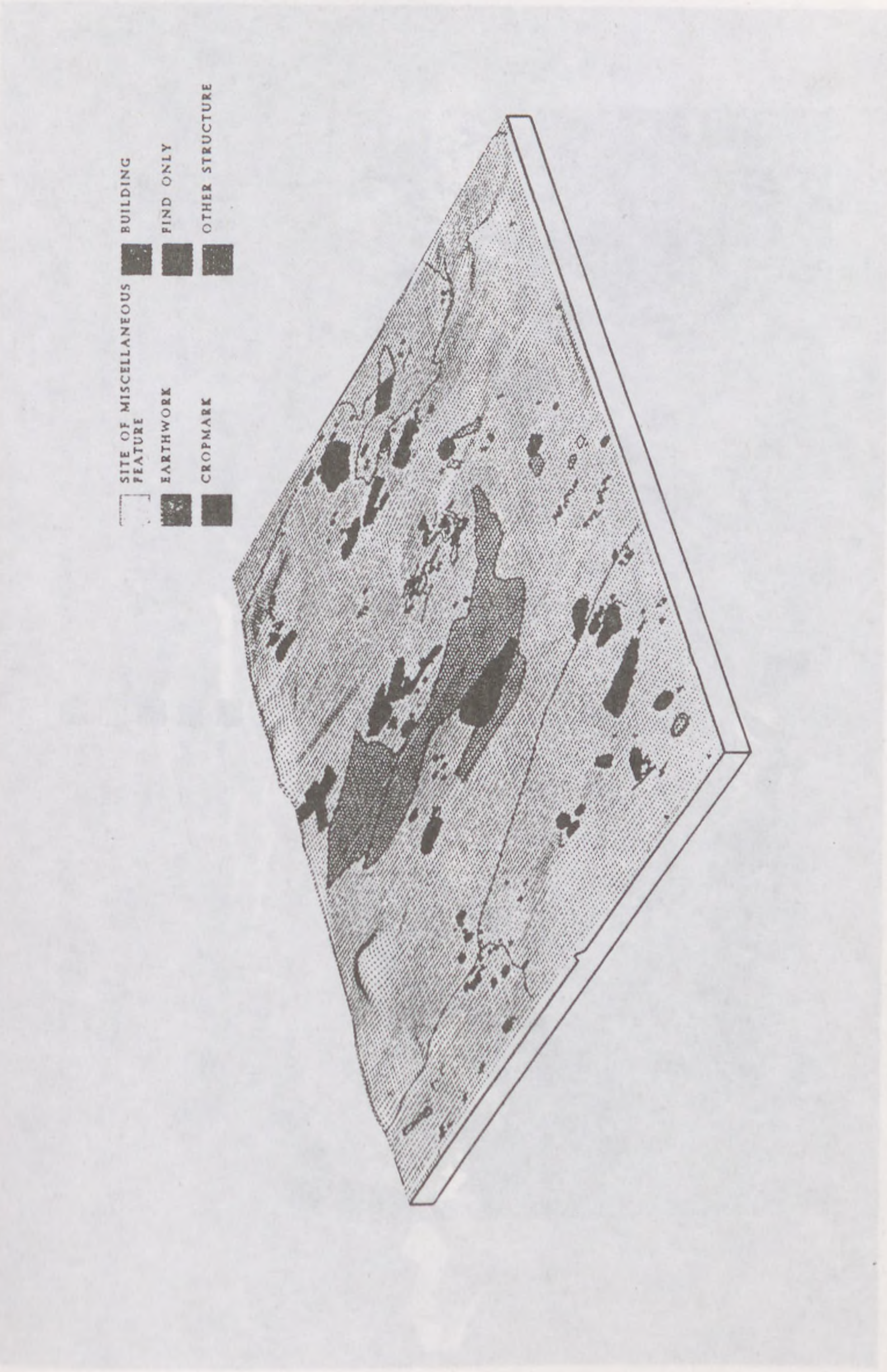
TOPOLOGY IS IMPORTANT

GIS-SEAMLESS MAP EXTENTS + WINDOWS

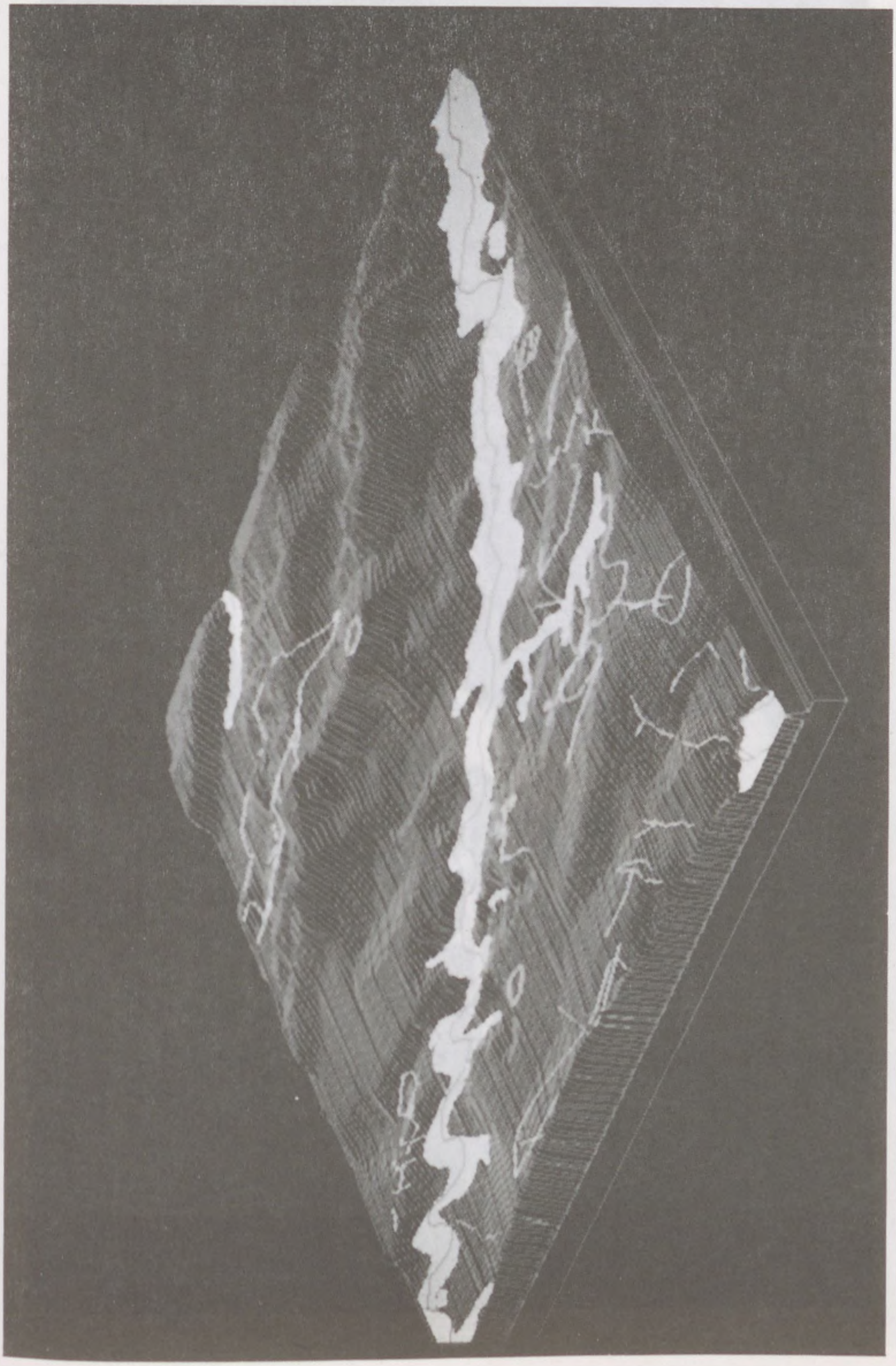


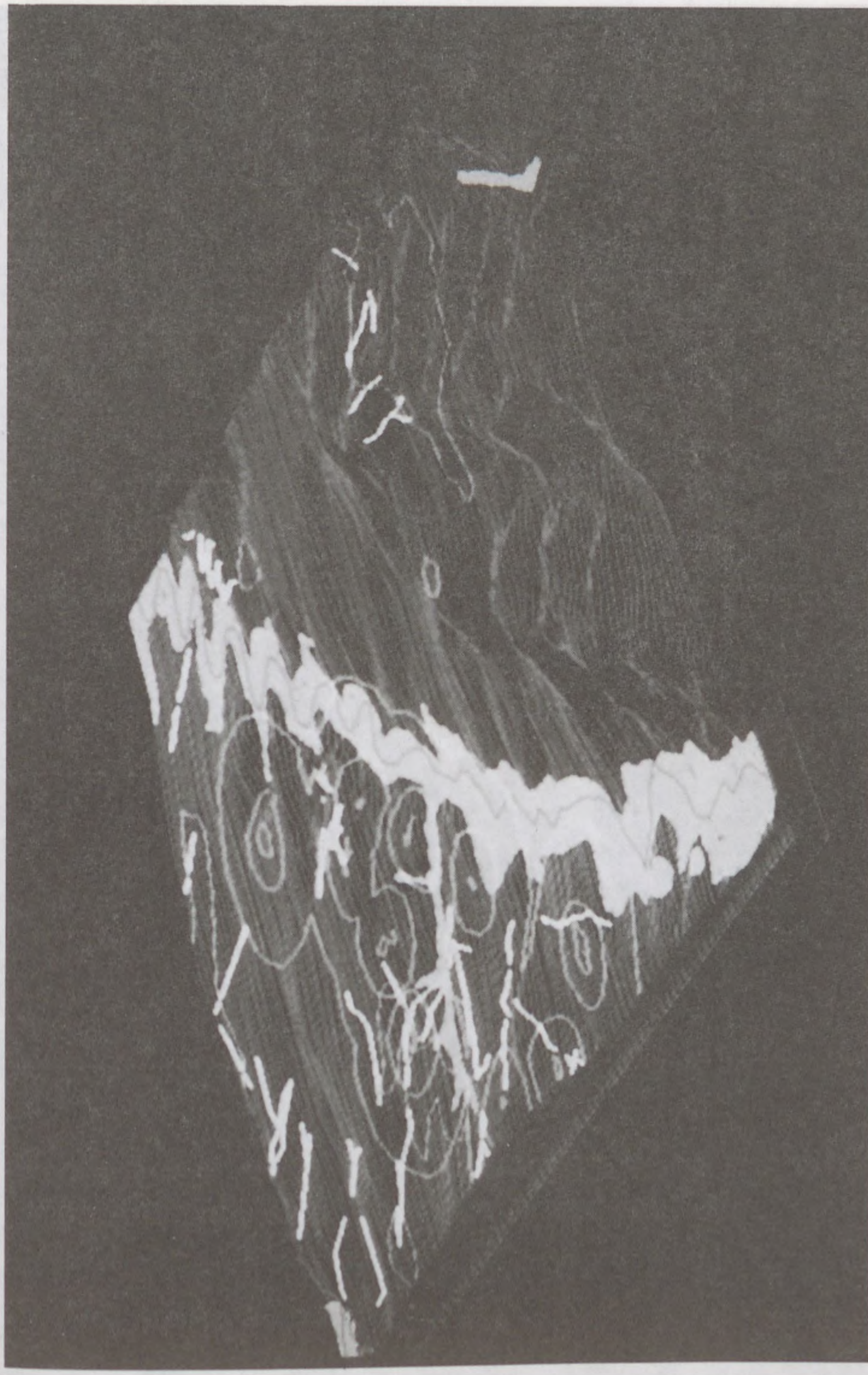
Area of interest for retrieval/analysis

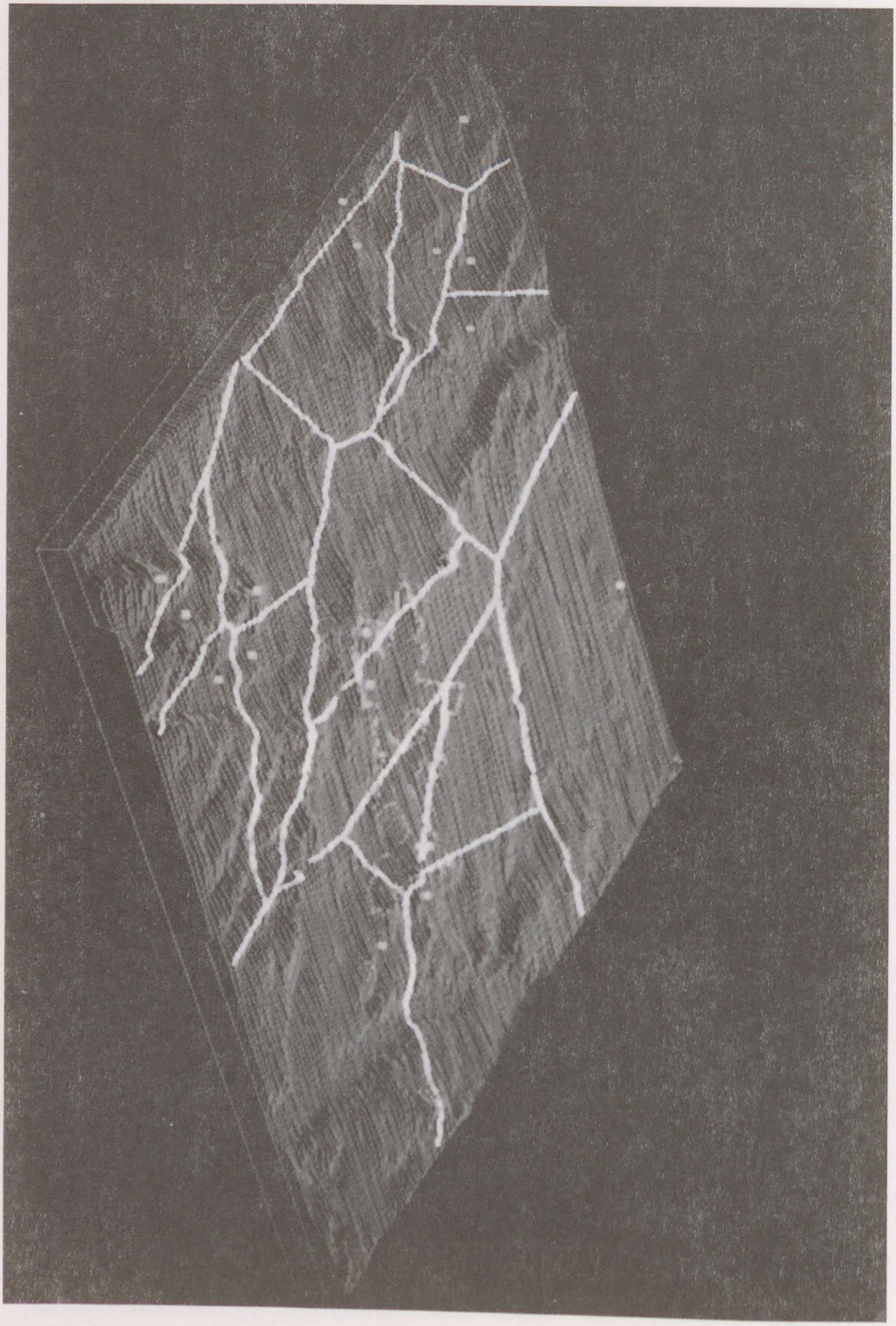
Library of map sheets as input

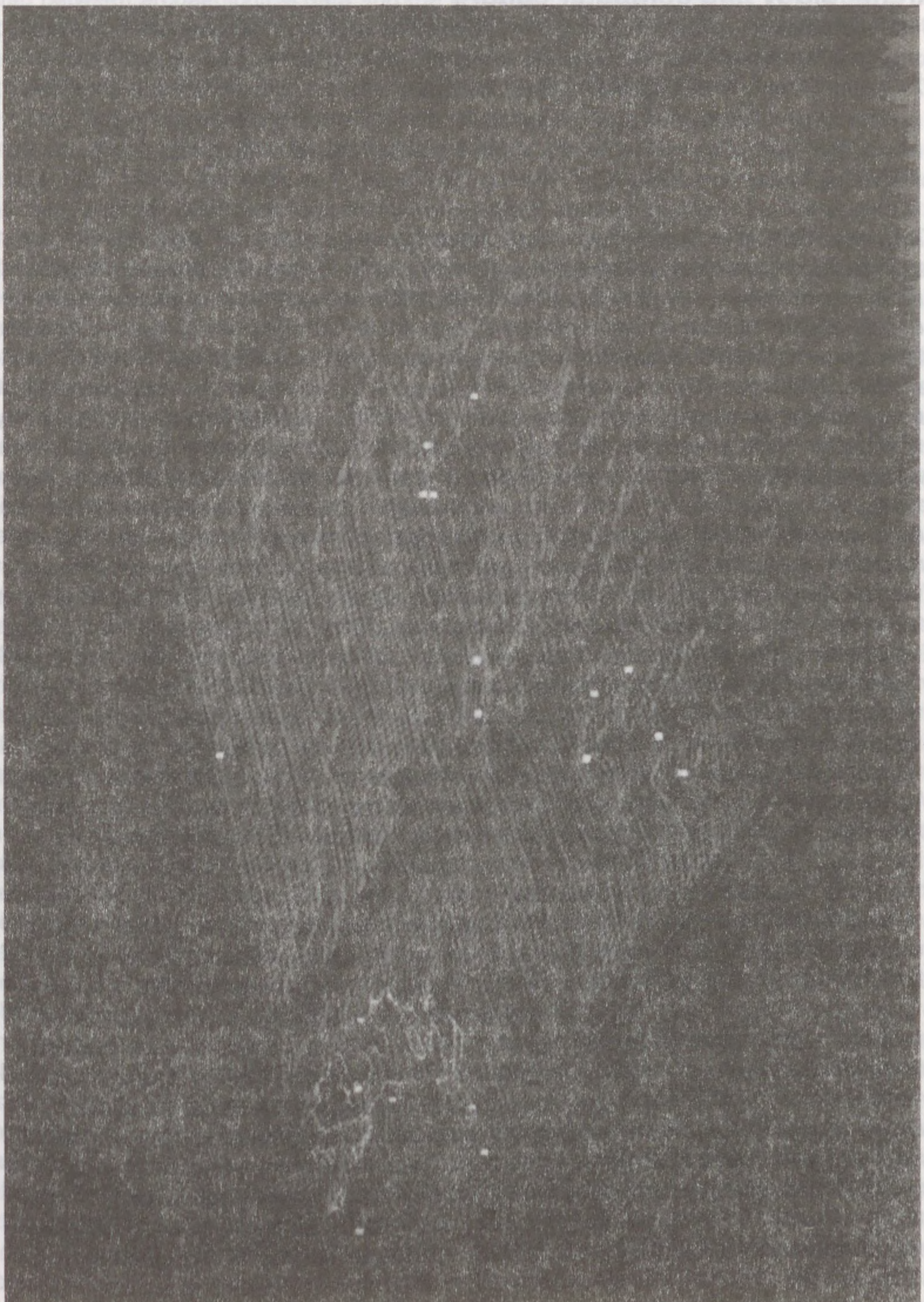

SITE OF MISCELLANEOUS FEATURE
EARTHWORK
CROPMARK
BUILDING
FIND ONLY
OTHER STRUCTURE


ALLUVIUM
KELLAWAAY'S CLAY SAND
1ST TERRACE DEPOSIT
2ND TERRACE DEPOSIT
3RD TERRACE DEPOSIT
4TH TERRACE DEPOSIT
MINING
LOWER CORALLIAN SLIP
SITE OF MISCELLANEOUS FEATURE
EARTHWORK
CROPMARK
BUILDING
FIND ONLY
OTHER STRUCTURE
ROAD WITH 100 METER BUFFER









Archaeology and computer culture

Sebastian Rahtz
ArchaeoInformatica
12 Cygnet Street, York Y02 1AG, UK

ABSTRACT

This paper discusses the implications of computer usage in archaeology, and the extent to which information technology must permeate all of our work. Traditionally, the use of databases, statistical analysis, expert systems, computerised mapping etc. have all been seen as additional tools for archaeologists; does there come a point at which a new way of thinking about archaeology itself, about perception and analysis, must be developed to take full advantage of the technology? The paper will use the area of excavation publication to develop some problems and ideas for the future. In the earlier part of the century, excavations were, at least in Britain, on a relatively small scale, and not very numerous. Academics and professional archaeologists knew about many of them while they were taking place; and when they were eventually published, they were easily assimilated. This was made easier inasmuch as they were written largely in a reader-friendly narrative style, with little use of statistics or other numerical analysis, and with minimal scientific input. Two factors have changed the situation radically since the 1960s. The first is the enormous expansion in field archaeology brought about by accelerating destruction of sites. The other is the equally dynamic improvements in technique, both in the recovery of vastly more information in the field, and in subsequent analysis; much of the latter has been in the realms of hard science, but has also been made possible by the rapid development of computerisation. The result has been that there are now so many excavation reports that no-one can hope to give them detailed attention, or even to know of their existence. Moreover, they have become very difficult to read or comprehend. Text has become more 'objective', tedious and less narrative; and there is a noticeable loss in the ability of archaeologists to use graphics as a medium of expression. A crisis is about arise, because the results of much important field work in the field have become difficult to assimilate, and too expensive to publish in full. Attempts have been made to deal with complexity by conventional means – micro print, microfiche, archives etc., and an attempt to separate 'data' from 'interpretation'; but these have often led to increasing frustration, because they often made a report much more difficult to comprehend, albeit cheaper to produce. We need radical approaches to make the excavation data more accessible and more comprehensible. It has been sufficiently demonstrated, on the one hand, that we can build hypertext versions of archaeological reports or other textual databases; on the other hand, we also know that we can formalise archaeological knowledge and reason at a high level about processes of interpretation. We are also familiar with the daily use of highly structured databases of low-level data, which are fast acquiring enhanced functionality with links to CAD or GIS systems; there is also experience (to a lesser extent) with the problems of networked access to such information. What we do not yet have, however, is any adequate formal model for the production of synthesised archaeological reports, and electronic access to these reports integrated with the backing data. There are two important additional aspects of publication of primary archaeological data: a) the availability of 'live' data about the archaeological heritage, and the implications thereof; and b) the relation-

ship between archaeological data and the rights of indigenous peoples. Should data be 'published' at all, and will the concentration of information in electronic forms be a harbinger of doom or hope for the third world? The paper will cover the use of electronic networks for information dissemination, and some experiments in this area.

This paper discusses the implications of computer usage in archaeology, and the extent to which information technology must permeate all of our work. Traditionally, the use of databases, statistical analysis, expert systems, computerised mapping etc. have all been seen as additional tools for archaeologists; does there come a point at which a new way of thinking about archaeology itself, about perception and analysis, must be developed to take full advantage of the technology? The paper uses the area of excavation publication, and electronic networks, to develop some problems and ideas for the future.

In the earlier part of the century, excavations were, at least in Britain, on a relatively small scale, and not very numerous. Academics and professional archaeologists knew about many of them while they were taking place; and when they were eventually published, they were easily assimilated. This was made easier inasmuch as they were written largely in a reader-friendly narrative style, with little use of statistics or other numerical analysis, and with minimal scientific input.

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A crisis is about to arise, because the results of much important field work in the field have become difficult to assimilate, and too expensive to publish in full. Attempts have been made to deal with complexity by conventional means – micro print, microfiche, archives etc., and an attempt to separate 'data' from 'interpretation'; but these have often led to increasing frustration, because they often made a report much more difficult to {\em comprehend}, albeit cheaper to produce. We need radical approaches to make the excavation data more accessible and more comprehensible.

"As new technologies change our understanding of communication, dissemination of information and publication, they imply changes in our notion of the fundamental activity of our discipline. The theoretical discussions of archaeology as a production of texts have to date conceived of 'texts' solely in terms of material printed on paper, but we need to adapt our archaeological rhetoric to current information technologies. This is an enormous undertaking. Indeed, it represents nothing less than rethinking the place of archaeology in a new world view" (Smith 1991)

We can make use of various information technologies to disseminate archaeological information: hypertext, formal description of documents, and networking. The former are considered below; the experience in archaeology with the problems of networked access to information is not very positive. Various uses have been made of academic networks to disseminate archaeological material. Krol:1992 gives an excellent explanation of the academic Internet network facilities (mail, file transfer, bulletin boards, information systems etc.), but the field is full of confusing jargon and different systems. The use of discussion lists has seldom reached academic heights (Figure \ref.{archl} gives a typical sample of the subject lines of mail to the ARCH-L. The list can be subscribed to by sending a mail message (subscribe arch-l 'your name' to listserv@tamvm1.bitnet), where 'your name' is replaced by your real name. in recent months; the mixture of gossip, simple news, and highly-technical questions make no impact on the development of true archaeology (useful as it is). The Gopher and WAIS information dissemination system (see Krol for details) has been used to pull together most of what is available on the Internet. Figure gopher shows the opening screens, where most of the information is technical reference, or administrative (the Yale service attempts to offer a directory of archaeologists).

The writer is not aware of any serious experiments to make 'real' archaeological information available over the international networks, and it is not clear that we are ready to cope with the implications (in terms of access, copyright, reliability etc.). But we are likely to see an increasing desire to take advantage of the physical links which are becoming available, even if only for personal communication; see the Introduction to (Reilly/Rahtz:1992) for some observations on the implications of this in archaeological and world politics.

Hypertext is a form of non-sequential writing. Documents are broken down into small self-contained units which are linked together in a variety of ways, and the reader is allowed to follow any path through the information. At its worst, it is little more than an electronic encyclopaedia, at its best it has all the virtues of the traditional book, and adds valuable extra facilities.

A good hypertext writing/reading environment will:

- Have hierarchical cross-reference links, so that the reader can at any time branch out and follow a train of thought;
- Also support hierarchical structures, so that the author can offer a traditional structure to the reader; this may be implemented by 'meta documents' which consist of a series of suggested links, a tour through the system;
- Allow executable procedures to be attached to links, so that normal programs can be run dynamically in the middle of a reading session; thus instead of having a 'canned' table or figure in the text, an external program might be called up to interpret up to date data and present a live analysis; still pictures, sound, and video will also be displayed.

Figure \ref.{sygraf} shows a dynamic site display which can be queried by the user, and re-excavated; -Provide graphical representations to display overviews of the whole 'document universe'.

The modern book will, of course, already perform some of these functions, as Table \ref.{navigation} shows. Hypertext is merely an electronic version of a well-written book; similarly, it can mimic the effects of a very poorly-structured book only too easily.

It has been demonstrated that we can build hypertext versions of archaeological reports or other textual databases; see the experiments of Rahtz {\em et al} at Southampton on, most recently, Rough Ground Farm; and the sophisticated success of the Perseus Project in the classical field (Smith:1992:caa, Mylonas/Heath:1990). Figure \ref.{cosm} shows an example screen from a {\em docuvers} about East African archaeology (from \cite{Rahtz/Sinclair:1993}). We have also seen very impressive museum-based multi-media systems (\cite{Makkuni:aia} and the work demonstrated in the 1991 Pompeii exhibition). Every archaeological unit or museum is aware of the possibilities of storing text and pictures on discs for access in some future environment.

The problem with hypertext is that it emphasises the distinction between two possible models of learning:

- The cognitive approach, whereby the reader associates together atomic 'facts' to build up a picture of reality, and all the facts form a network of links and supports. Here, the author simply needs to have all the information available, and provide mechanisms for the reader to put together a private associative pattern;
- The procedural approach, in which the author marshals and the information and presents it to the reader as a waiter delivers a meal, taking us from inference to inference, explicitly representing subordination and domination; this is the model of the traditional teacher, expounding a viewpoint.

The book, generally, forces the latter approach and the hypertext system promotes the former. With a change in delivery method, it is important that we writers use it correctly; we have been brought up to understand one sophisticated system (the book), and we take our knowledge for granted. Now we must, like an adult learning a new language, {\em force} ourselves to understand new techniques.

Formal archaeological reports

There has been a reasonable amount of success in formalising archaeological knowledge and reasoning at a high level about processes of interpretation (see the work of Gardin (e.g. \cite{Gardin/etal:1987}), Barcel\'o (\cite{Barcelo:1992:caa}), Dallas (\cite{Dallas:aia}) and, most important, Arthur Stutt's work at the Open University and Southampton University–see, e.g., \cite{Stutt/Shennan:aia}). At the other end of the spectrum, we are also familiar with the daily use of highly structured databases of low-level data, which are fast acquiring enhanced functionality with links to CAD or GIS systems. What we do not yet have, however, is any adequate formal model for the writing of synthesised archaeological reports, and electronic access to these reports integrated with the backing data. This is not to go along with Gardin's ideas about mathematical representation of archaeological knowledge, but to point out that our existing books and papers lack a formal definition which will make them amenable to automatic processing.

The laudable work on standards in archaeology in areas like graphics, site databases, bibliographies, and standardised vocabulary has not yet resulted in agreement on the archiving of textual material. The very large number of excavation reports now being prepared electronically by archaeologists may well be a useless resource unless they are written or archived using a sufficiently general form of mark-up, rather than simply prepared for page makeup. (See \cite{Coombs/etal:1987} for a classic explanation of why generic mark-up is desirable.) Although its use in archaeology is limited, there is an appropriate ISO standard for preparation of electronic book sources, using generic textual mark-up. This is the Standard Generic Mark-up Language (SGML; see \cite{Goldfarb:1990} for a full specification, and \cite{Herwijnen:1990} or \cite{Barron:1989} for a more readable introduction), a language for describing the structure of documents.

It does not dictate a specific set of codes to use, but provides a grammar in a description of the codes must be written. This allows the recipient of a document to verify it against a description, and to process it automatically. Extensions of SGML (HyTime) allow multimedia documents to be described, and this allows software-independent hypertext sources.

An SGML-conforming document consists of text interspersed with commands (generally delimited by \verb| and \verb|| characters) which describe what the purpose of the text is. All the commands must be defined in a Document Type Description, which dictates what elements may be used, how they relate to one another, and how they are written. The start of an example DTD is given in Figure \ref.{dtd}; it is not necessary to understand this in detail, simply to appreciate that it lists unequivocally all the commands that will appear.

Given this DTD, the start of a report would look like Figure \ref.{header}, containing the same information as a conventional title page, but specifying what the elements mean. This book could be trivially processed to find the name of the site, and the periods represented therein.

A more typical piece of archaeological text is shown in Figure \ref.{mark-up}, with the corresponding conventional printed version in Figure \ref.{formatted}. On the conventional page, the Pit number (552) is signalled by the use of bold type (the sort of intuitive convention most readers will follow), whereas in the mark-up it is explicitly tagged as an element of type 'feature'.

Unfortunately, of course, not all data is amenable to this type of mark-up. Consider the following (real) piece of report:

An oval enclosure, 56, whose ditches were recut many times, was occupied from the mid-1st to the mid-2nd century AD. The ditches contained domestic refuse and the enclosure probably surrounded a house; a short arc of postholes on the inner lip of one ditch circuit may have been part of this. The size of the enclosure varied from 9 m to over 20 m from front to back, but it was not possible to establish the sequence of the ditches. One or two of the ditches could have held a wall or fence slot (Fig M10). Outside the entrance was a group of pits contemporary with it, mostly filled with dark occupation soil including charcoal and domestic refuse (Fig M11). The pits could have been used for storage, and one or two may have been lined with stones. One or two pits contained only Iron Age pottery, and may have been prehistoric.

It is not unreasonable to read this kind of report, and ask questions like:

– What is the earliest phase on the site associated with wheel-thrown pottery?
– Did you have any square stone buildings?
– To what extent does this site differ from others of its supposed period?
– Were there any post-holes associated with coins of Tetricus in features interpreted as religious?

Which it would be extremely difficult to represent in mark-up. This means that properly marked-up books in a large textual archive would still not be suitable for meaningful searching. We must therefore continue to consider the ideas of Stutt and Gardin, and find some common ground between them.

The future of generic mark-up like SGML will probably be driven by software; when the big word-processors vendors add SGML-compatible export to their products, its use will increase dramatically. Software which manipulates SGML documents at present is either commercial and expensive (or Soft Quad {\em Author / Editor}), comes from research groups for specialised purposes (e.g. University of Waterloo {\em PAT} \& {\em LECTOR} search and display software developed for the Oxford English Dictionary), or public domain academic which is not suitable for the casual user (e.g. Clark's SGMLS parser and translator and the Qwertz SGML \LaTeX\ translator (\cite{Gordon:1992}); cf \cite{Sperberg-McQueen: 1991})

The use of SGML so far has been limited to large organisations and projects (most famously the Oxford English Dictionary and the ATOS and CALS projects of the USA Department of Defense). The Association of American Publishers actively promote it for publishers, and the humanities consortium of the {\em Text Encoding Initiative} has produced guidelines for the mark-up of scholarly material.

The advantages of SGML mark-up are that:

- It is not tied to any country, institution or system; it deals with all languages and publishing systems;
- It is thorough, comprehensive, and linked to other standards;
- It has a structure by which documents can be validated;
- It encourages non-printing mark-up;
- It is an ISO standard.

But its disadvantages for the average archaeologist are that:

- It is not a system that does anything for the casual user; it needs formatting software to produce printed pages;
- It is tedious to read and write at present;
- There is little useful public domain or popularly-priced software;
- It imposes a discipline upon writers which they are unwilling to accept.

Few archaeological groups will gain {\em immediate} benefit from adopting a policy of archiving material in SGML mark-up. There is no established academic practice of serious exchange, or searching, of archaeological documents, although there is plenty of uncritical archiving. But if archaeologists want to participate in the global database, there is very little choice but to start putting the textual house in order. The great virtue of (and problem with) SGML is its complexity; the committee which put it together took a very wide view of the subject, and it is hardly conceivable that archaeologists need to worry that they have problems not dealt with in the standard.

Conclusions

This paper has briefly looked at some of the technologies which may change our methods of presentation. The challenge facing the archaeologist is how to cope with \text{delayed evaluation}, where there is no longer a need to publish or promote one single interpretation, but leave it to the reader to follow her own path through a web of data. In the well-written excavation report, this has always been to some extent true; the author will have clearly separated interpretation from data, but inevitably the linear nature of printed books will have emphasised one approach over another. The danger we face is that authors will feel completely absolved from the responsibility of any sort of interpretation.

It {\em is} important that archaeologists develop their 'computer culture'. The technology {\em per se} does not do very much that was not possible before, but it does change the default way of working. As geological changes make a river take a different route to the sea, so the changes in the way information is presented electronically mean that the archaeologist will be pushed into different types of publication. Only by understanding the technology can we dictate what happens, and attempt proper understanding of material culture processes, rather than drowning in a sea of half-digested data.

JANET	Joint Academic Network—links UK Universities and research institutes
Arpanet	Original USA network, set up for the defence industry
Internet	Main international academic network, normally Unix machines and VMS, using TCP protocols
BITNET	large world-wide academic network based on IBM mainframes and systems
VNET	IBM internal network
NetNorth	Canadian network
EARN	European Academic Network, linked to BITNET
uucp	'unix to unix copy': a loose network of communications between Unix sites, operating on a 'pass the buck' principle
X25, X29, TS29 etc	*Protocols* for how sites are to physically communicate; X25 is the current standard in the UK, to be replaced by X400 at some point
Ethernet	A physical network standard
TCP-IP	TCP is the virtual circuit protocol of the Internet protocol family. It provides reliable, flow-controlled, in order, two-way transmission of data.

Table 1: Academic networking concepts

Date	*Subject*
91 12	Re: Communion of Suffers
91 12	Re: Thermal Treatment of Non-Flint lithic Material
91 12	AIA meeting
91 12	Reminder abt UNSUB/MAIL
92 06	JOUKOWSKY FIELD MANUAL
92 06	Re: WAIS
92 06	archaeological wais server
92 06	UISPP Comm. IV meeting, Australia
92 06	bibliography of archaeological computing, version 2
92 06	death
92 06	Lost Ark
92 06	Fred Plog
92 06	DBaseIII Compiler
92 06	address

Figure 1: Some typical messages on ARCH-L

```
    1.  ANU/

    2.  ARCH-L/

    3.  ASOR/

--> 4.  Anthropology and archaeology gopher sources (Yale, UWA)/

    5.  Archaeological Computing bibliography (WAIS database)/

    6.  Clonehenge/

    7.  Conservation OnLine (cool) (WAIS databases)/

    8.  SyGraf/

    9.  WAC/

......


             Menu for Anthropological Resources

       Anthropology and archaeology gopher sources (Yale, UWA)


--> 1.  About the Anthropology and Archaeology Archives.

    2.  Directory of Individuals and Departments/

    3.  Help and Documentation/

    4.  Information for prospective students: Courses of Study/

    5.  Menu for Anthropological Resources/

    6.  Newsgroups/
```

Figure 2: Gopher on ftp.tex.ac.uk

Book tool	*Theoretical effect*
Title page	top level summary
Contents page	browse tree
Book thickness	coarse navigation
Running heads	medium navigation tree
Section headings	fine navigation tree
Fonts	data typing
Cross-references	non-hierarchical links
Index	alternative hierarchical view
Pictures, tables, lists	atomic node types
Glossaries & footnotes	hidden modules

Table 2: Navigation methods (from Rahtz *et al* 1992)

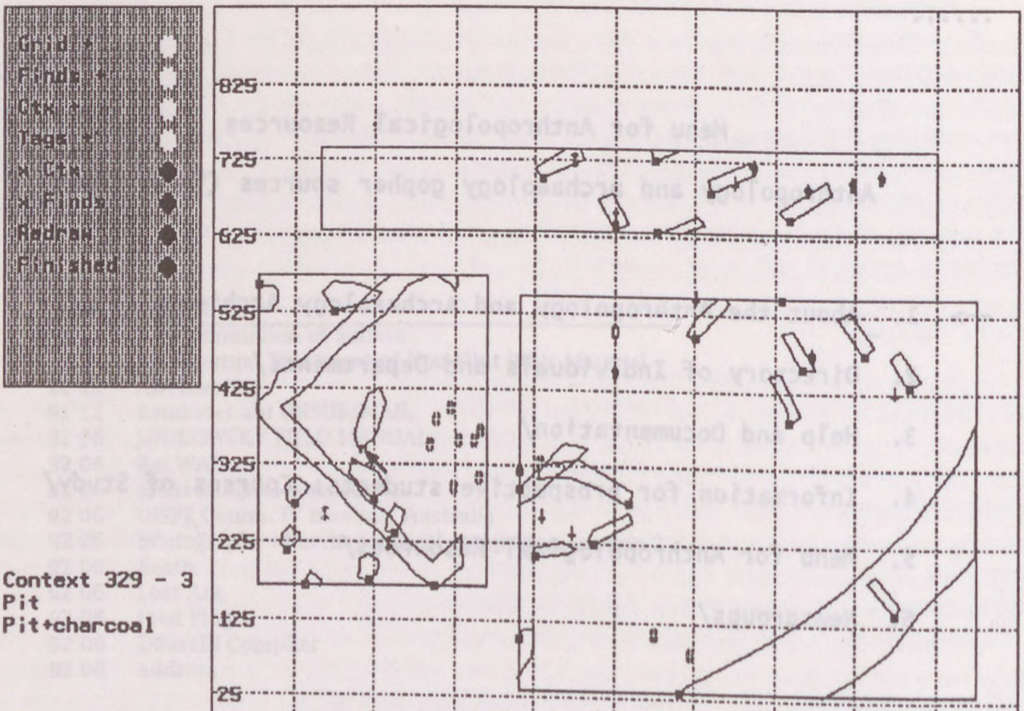

Figure 3: Example of dynamic site display (from SyGraf, Rahtz 1991)

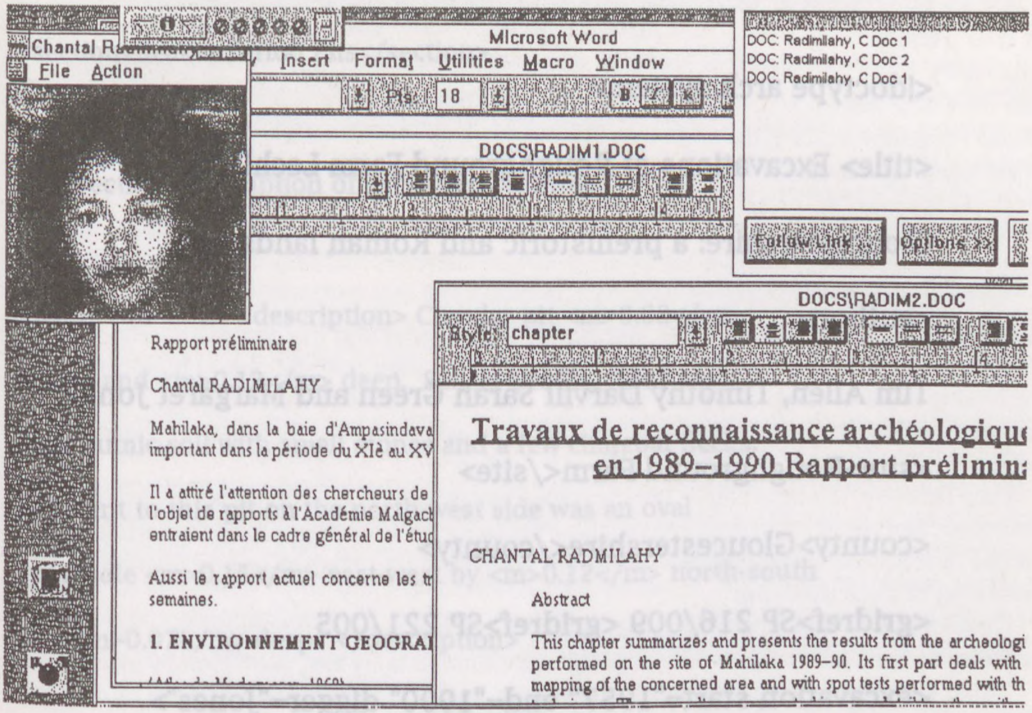

Figure 4: Example of archaeological hypertext

```
<!element arch o o
     (article | report | book | archive>
<!element report - -
     (titlepag, header?, abstract?, toc?, lof?, lot?, p*,
      chapt*, (appendix, chapt+)?, biblio?) +(footnote)>
<!element titlepag o o (title, author)>
<!element title - o (#pcdata, subtitle?) +(newline)>
<!element subtitle - o (#pcdata)>
<!entity %sect "heading, header?, p* " >
<!element chapt - o (%sect, sect*) +(footnote)>
<!element sect  - o (%sect, sect1*) +(footnote)>
<!element sect1 - o (%sect, sect2*)>
<!element sect2 - o (%sect)>
```

Figure 5: Document Type Description — elements

```
<!doctype arch system>

<title> Excavations at Roughground Farm Lechlade,

Gloucestershire: a prehistoric and Roman landscape

<author>

Tim Allen, Timothy Darvill Sarah Green and Margaret Jones

<site>Roughground Farm</site>

<county>Gloucestershire</county>

<gridref>SP 216/009 <gridref>SP 221/005

<excavation start="1957" end="1990" digger="Jones">

<period name="Neolithic" start="-2000" end="-1000">

<period name="Iron Age" start="-500" end="0">

<period name="Roman" start="100" end="450">
```

Figure 6: Report header

<section>Beaker Period Pits</section>

<subsection>Description of excavated features

<feature id=552> <description> Circular pit <m>0.68</m>

across and <m>0.12</m> deep. Saucer-profile, filled with

dark humic soil with small stones and a few charcoal flecks.

Adjacent to this pit on the north-west side was an oval

?posthole <m>0.15</m> east-west by <m>0.12</m> north-south

and <m>0.07</m> deep. </description>

<finds> Finds: Pottery <ref figid=9>

P7, P8, P9, P10, P11, P12, P13,

P14</ref> </finds></feature>

Figure 7: Excavation text (Markup); from Rahtz *et al* 1992

Beaker Period Pits

1. Description of excavated features

552 Circular pit *0.68 m* across and *0.12 m* deep. Saucer-profile, filled with dark humic soil with small stones and a few charcoal flecks. Adjacent to this pit on the north-west side was an oval ?posthole *0.15 m* east-west by *0.12 m* north-south and *0.07 m* deep.

Finds: Pottery (Fig. 9: P7, P8, P9, P10, P11, P12, P13, P14)

Figure 8: Excavation text (Formatted); from Rahtz *et al* 1992

Access to Insights: stimulating archaeological visualisation in the 1990s

Paul Reilly
IBM UK Laboratories Ltd, Hursley Park, MP 104, Winchester
United Kingdom SO21 2JN
email. reillyp@winvmd.vnet.ibm.com

ABSTRACT

Advances in computer technology, especially 3D imaging and the rise of so-called virtual environments, are forcing archaeologists to reapplies their perceptions of their data, and are having a particularly dramatic affect on how they visualise their material. They also have radical implications for how archaeology will be conducted, taught and presented in the future.

Until recently, the application and development of data visualisation and computerised reconstruction methods in archaeology was restricted to a small group of researchers with access to research systems, often requiring considerable experience and training in programming of such systems.

Restrictions of availability, access, usability etc. are now largely overcome by off-the-shelf advanced systems with their sophisticated functionality and user-friendly interfaces.

Using experimental studies using auger data, we demonstrate some of the latest data exploration potential of systems that enable multiple visualisations of large, complex, multi-dimensional data sets to be realised in environments which do not require deep knowledge of computational methods.

This increased freedom to explore multi-dimensional data sets opens the way for further insights into the nature of three-dimensional deposits and their recording to be gained. These ideas can be extended into the realm of interpretation where, for instance, we can begin to explore alternative reconstruction and start to devise visual cues to indicate how confident we are about selected elements of the computerised model.

This paper will illustrate and explore these ideas, and discuss their implications to how archaeology is practiced and taught, using recent examples of computer-based reconstruction and virtual archaeology experiments.

Introduction

Data visualisation refers to the practice of visually exploring data which have been converted into displayable geometric objects. However, it is more than the application of geometric modelling, graphics or imaging techniques. Visualisation is an interactive process in which large, complex datasets are brought within the range of human experience and cognition, and where new insights are stimulated. As such, visualisation should appeal to the archaeological community. It might therefore appear curious that relatively few archaeologists have, as yet, embraced the approach.

Why is this?

The short answer is that a combination of circumstances have deterred or prevented archaeologists from exploiting what can be a highly effective tool. Access is the most critical factor determining whether or not significantly larger numbers of archaeologists will in the future incorporate visualisation methods into their repertoire of analytical procedures (see Reilly & Rahtz 1992, especially pp 18–20).

The meaning and the relevance of the term 'access' in the present discussion has several facets. Archaeologists first need access to the knowledge of what visualisation approaches are available and possible. Of course, to pursue visualisations, physical access to the technology of visualisation is prerequisite. But physical access is useless unless the archaeologist also has access to the skills necessary to manipulate this technology properly. Correct usage is not just following the correct procedure for a given technique, but knowing which approaches are suitable for a given situation.

We should also recognise that individual archaeological researchers are members of a wider community, so in order to share the fruits of visualised insights archaeologists require access to the media for transmitting, or disseminating, visualisations, including all the data interactions.

Conversely, the wider community of interested parties can only share such insights if there is access to the results of visualisation (i.e. publications), ideally with all the data. If we wish knowledge to be shared outside the circles of specialists the wider audience must be capable of understanding and appreciating all that is encapsulated in a visualisation. In other words, the wider community must have access to the education and training needed to be able to 'read' and comprehend visualisations. Access is therefore not just a technical or economic issue. There must, in fact, be a culture of visualisation in which the wherewithal for visualisation is almost be taken for granted. (Whether this is desirable is a matter to be discussed elsewhere).

Access to visualisation methods has been restricted because, amongst other things, suitable visualisation hardware was relatively rare and expensive and the prevailing programming paradigm was generally considered too arcane by the average archaeologist. Moreover, since advanced visualisation by its nature tends to be hardware dependent, advocates of the approach have been severely hindered in their efforts to pursued colleagues of the full power of such systems, because conventional publication methods can not capture, or adequately convey, those extra dimensions and details, which enhance the richness and clarity of multidimensional data sets, that are the essence of visualisation.

The simple reality is that without direct experience the majority of archaeologists have not been in a position to appreciate the benefits of exploring data through visualisations. It is therefore not entirely surprising that many remain sceptical and ignorant of the approach. However, as we move through the 1990s we can expect this situation to change rapidly, and radically, in response to the challenge of handling ever larger data sets, technological advances and, crucially, much greater access to visualisation technology.

Technological Trends

Although its roots are much older, data visualisation emerged as a distinctive discipline only in the last five or six years. During this period there has been a constant stream of archaeology projects which have won a great deal of visibility through the application of visualisation (see Reilly 1992a). As the number of projects where visualisation methods are employed successfully grows, new levels of expectation are inevitably being established in the minds of both the archaeological community, who generally want to be up-to-date professionally, and an increasingly sophisticated public, who expect the highest possible presentation methods to be adopted.

A further consequence of both the profession and the public being exposed to the latest methods of representing and annotating data, is that quite high levels of abstraction are generally recognised and understood. More and more people know how to decode, or interpret, complex data presented graphically. For example, metadata (information about the data) can be included to help audiences distinguish between measured, extrapolated, or postulated, data. Thus, colour and shape might be used to represent an object, property or value, and transparency or brightness could be used to signify whether a given detail is measured or inferred.

We have already intimated that one of the major inhibitors to adopting graphics - or imaged-based exploration methods was the limited ability of general purpose machines to handle data sets of any size. A particular restriction was the amount of memory found in the typical computer available to the archaeologist, which meant that only small sets of data could be examined at one time. The importance of this inhibitor is declining rapidly, because memory and storage are now capable of holding previously unimaginable amounts of data and, at a conservative, estimate the capacity of an average personal computer is being doubled every twelve to eighteen months.

Another important limitation was the relative primitives, not to say poor quality, of the graphics that could be displayed. Not long ago an 8-bit EGA system was 'de rigor' in computerised archaeology circles, but was competing with the VGA standard and, latterly, SVGA and XGA resolutions have become popular display standards.

In the background there are several 24-bit HDTV (High Resolution TeleVision) standards vying for predominance in the marketplace. With higher resolutions, and an emphasis on accurate representation as well as picture quality, we should expect to see a move away from polygon- to pixel-based rendering, using general purposes processors instead of the various special adapter cards which are fashionable at the moment. (When one is interested in quality graphics pixel-based calculations are preferred. It is for this reason that all the major special effects companies use pixel-based systems).

The move towards pixel-based rendering also makes more sense when one considers that polygon calculations are redundant at the sub-pixel level. The impact of this extraordinary increase in the power, capacity and function found in personal computers has so far been most striking in the growth of imaging in archaeology, with large numbers of archaeologists all over the world now habitually applying image-processing techniques to their data (e.g. Booth, Ipson & Haigh 1992; Forte 1993; Hasek, Petrova & Segeth 1993; Lemmens, Stancic & Verwaal 1993; Scollar, Tabbagh, Hesse & Herzog 1990).

Image-processing techniques have also been adopted, adapted and enhanced in raster-based Geographic Information Systems (GIS), which has also become a familiar package on the archaeologist's personal workstation (e.g. Allen, Green & Zubrow 1990; Lock & Harris 1992).

Both technologies (imaging and GIS) are beginning to extend beyond investigations of two-dimensional 'images' to three-dimensional volumes (Reilly 1992a, 169–170). Here, as we talk of volumetric and other high-dimensional data, we beginning to encroach once more on the world of advanced computer graphics and visualisation.

Gradually the boundaries between these disciplines are becoming blurred because of areas of common interest (see, for example, Powlesland & Donoghue 1991; Hetrick et al 1992).

It is at the level of the workstation that the pace of change is fastest and most exciting; workstation-based visualisation is now both flexible and powerful. Many graphics functions which, even two or three years ago, were considered advanced, perhaps leading-edge, technology, and available only on the most expensive workstations, are now finding their way down into the low-end personal workstation which already feature fast, bright screens and powerful adapters and processors. For instance, real-time animation was until fairly recently a relatively rare feature, to be found only on specialist workstations.

Few people are now surprised to see simple, but effective, low-resolution animation running on even the most modest modern general-purpose workstation, and there is also a growing list of very sophisticated animation produced using readily available systems (Chapman 1992). For example, a team lead by Rocha and Custodio has produced remarkable animation studies of a rendered CAD reconstruction model of the early Jesuit mission of Sao Miguel Arcanjo, Rio Grande do Sul, Brasilia (Rocha et al 1993). As part of Projeto Missoes, the mission's surviving masonry was recorded photogrammetrically and digitised. The resulting stonework 'patterns' were then subjected to a series of texture, colour and tonality experiments before being mapped on to the computer model of the mission for rendering.

All the modelling, rendering and animation was carried out on Intel 386- and 486-based IBM compatible computers, using Auto CAD, Auto Shade, Render Man, Animator, Animator Pro and 3DStudio.

The trend is clear: what is currently considered esoteric and prohibitively expensive will become commonplace and affordable within a short period of time.

Some hint of tomorrow's world of visualisation, in the typical archaeological institute or unit, as the turn of the millennium approaches, is discernible as emergent developments in leading-edge projects which are attempting to address today's most challenging problems.

One of the greatest challenges facing researchers in all disciplines is the problem of processing the colossal amounts of data being generated. Many data-sets are made intractable by virtue of their vastness, so it is not unusual to make such large datasets manageable by reducing their rich internal complexity through data abstraction conventions and sampling procedures. Paradoxically, each new generation of machines also make it possible to create, as well as analyse, increasingly large volumes of data. Of course,'large' is relative description. Today's most advanced visualisation engines can handle enormous datasets in memory, possess multiple super computer processors with very fast inter-connectivity, as well as having very high bandwidth input and output channels. In quantified terms, this means that sequences of data, occupying terabytes of storage can be processed on a daily basis. For instance, a state-of-the-art system designed specifically for complex scientific data visualisation, such as the IBM POWER Visualisation System (PVS), may boast up to 32 parallel Inmos i860 processors (i.e. 2.5GFLOPS), up to 2.5GB of memory, High Performance Parallel Interface (HIPPI) channels for data input at up to 56MB/sec per channel and up to 100MB/sec for screen output, via a 'Video Controller' which supports several screen formats, including 1280x1024, 1920x1536 and 1920x1024 (i.e. HDTV).

The remorseless march of technological advance will doubtlessly bring such systems to the desktop in due course. Hardware performance improvements by themselves, however, are not a strong enough catalyst to stimulate the widespread application of visualisation.

Software is an equally important consideration.

Here too we can detail dramatic advances in the state-of-the-art, with a growing number commercially available visualisation packages now enabling archaeologists with little or no formal training in computer science to subject their data to sophisticated data visualisation investigations. For instance, several large data sets collected on different sampling grids can be registered and visualised simultaneously. Conversely, the same data can be displayed in a number of ways within the one or more visualisation.

The range of combinations is staggering. Access to explore this software (and the hardware it runs on) is being broadened through significant advances in interfaces. A key aspect of user acceptance in the archaeological community is that the 'skill level' – in terms of programming ability – required to realise complex data transformations for visualisation purposes, is being reduced rapidly by means of visual programming interfaces (e.g. Shu 1989). The visual programming paradigm offers considerable power over the flow of control and functionality within an application, especially in data exploration projects.

Integrated computer tools, specifically designed to convert primary data into visual objects to enable exploration and stimulate insight, are already available. Equipped with a simple 'point and click' interface to a small number of very powerful, but easy-to-use, functions, the serious data explorer is enabled to import and export, annotate, realise, render, interact with, transform and probe data (e.g. Reilly & Thompson 1993). As a result, the archaeological investigator is freed to spend more of the available time investigating or refining the data, rather than handling the intricacies of graphics programming.

The data explorer also has more control over the conventions developed and used to explore and present archaeological phenomena. From now on, we can expect to see many more archaeological data explorers being both willing and able to use visualisation systems; they have reached a level of user-friendliness that allows the archaeologist to focus on the archaeology and not be distracted by the complexities of programming. This means that our highly developed quantitative approaches (e.g. Aldenderfer 1987; Shennan 1988; Fletcher & Lock 1991) can now be complimented with sharpened qualitative abilities brought about by visualisation environments that allow interactive exploration of the meaning of large and complex data sets.

To summaries the above discussion, it is abundantly clear that as we move through the 1990s archaeologists will have much more processing power, the technology will be easier to use and it will be more affordable. However, despite vast improvements in the technology, one other vital factor still needs to be satisfied to stimulate the general adoption of visualisation.

Archaeological Visualisation and the Public

Probably the most important conducive factor for making an environment where archaeological visualisation can thrive is the existent of widely publicised 'successful applications' – applications which capture the imagination and are perceived as successful, exciting and worthwhile. Such projects are necessary to set standards and expectations.

The importance of exemplary projects should not be under-estimated. In the short term, the provision of such exemplars is unlikely to stem from the investigative elements of archaeology, even though scientific data exploration of large high-dimensional data sets will certainly be an important research area (see Reilly & Thompson 1993). Initially, the greatest demand for visualisation in archaeology will probably stem from the need to present monuments and sites in more flexible and interesting ways.

In other words, the catalyst for visualisation will not be found in improved ways of discovering new knowledge but in improved new ways of presenting established knowledge to the public. This suggests that the heritage industry (especially museums) will take the lead in these developments. Certainly, they are well-placed and have the resources and motivation to capitalise on visualisation approaches; besides being increasingly under growing pressure to find new ways of educating the public to appreciate and support their work (especially through paying visits to exhibitions and monuments), museums and heritage bodies also have large amounts of the essential raw materials need to create visualisations that capture one's imagination. In particular they have access to the plans, drawings and other archival material relating to many well known and important 'sites'. Fortunately, archaeological and architectural recording can be readily computerised and many the drawing offices of many heritage bodies have already exhanced their drafting skills far beyond line drawings on plastic film through the use of CAD (Computer Aided Design) and CADD (Computer Aided Drafting and Design) systems (e.g. Wood & Chapman 1992). CAD systems are used to record excavations and monuments to provide a versatile site archiving tool, which has the added value of being suitable for generating multiple views, elevations, plans and so on to defined scale. Each object can be associated with other data housed in a data base (e.g. Alvey 1989) and are thus also valuable research tools. Moreover, electronic devices such as the pen-plotter are making the transition from paper to computer almost transparent (e.g. Schwerdtner 1992).

All these factors mean that the skill-base needed to use CAD in archaeological planning is largely already present and resistance to the technology is not great. CAD systems are having a profound affect on the attitude of both archaeologists and the public to the use of visualisation, and computerised methods, in the understanding, protection and management of archaeology and cultural heritage generally. This is not because a CAD system in itself is intrinsically more powerful or produces more spectacular graphics or animation than other modelling systems, it is because CAD is a technology which is both conservative and revolutionary at the same time. CAD systems occupy a special position in terms of the relationship of the traditional recording methods and conventions of archaeologists and architects to the new possibilities of representation and expression engendered through modern computation and display technology.

CAD systems are easy to use in the sense that they are comfortingly familiar; replicating the time-honoured two-dimensional drafting techniques for inputting plans and elevations. Itemising the immediate advantages that automation brings to this well-established craft of draughting is not hard to do. However, the single most important advantage is probably that drawings are simpler to manipulate, with commonly required transforms, such as the integration (or overlaying) of different combinations of drawings (and the facility to rescale them) being available at the press of a button.

Drawings held in digital format are also more convenient for storage, exchange and duplication purposes. CAD is clearly attractive to archaeologists. CAD also has other, perhaps, unforeseen benefits. For instance, the ease with which recorded data can be manipulated is not translated solely into productive gains brought about by increased efficiency. Previewing, for example, encourages reviewing and spawns experimentation and increased interaction with the data. In fact, one could argue that CAD manifests a propensity to foster data exploration.

CAD/CADD systems, like most other computerised technologies, continue to expand and improve the function they offer. Bolt-on modules provide a growing variety of powerful display techniques beginning with scaled, colour-shaded, perspective views of the recorded details or reconstruction. In addition rendering packages – which are becoming very sophisticated indeed – are able to take output from most packages as the data exchange conventions have established 'de facto' standards (Chapman 1992; Davenport 1993).

The special effects we see in the block-busting movies of recent times, such as 'The Abyss', are perhaps the best known expression of the art. However, many people are probably not aware that most of the products being promoted in our television commercials are also digital creations and not filmed objects. The use of these advanced rendering packages is not restricted to the entertainment and advertising industries alone. Thompson Digital's TDImage is a good example of a system for interactively creating and animating three-dimensional images that is designed for a broad spectrum of users, including industrial designers, creative artists, architects and engineers. TDImage provides a full interactive image production line, from design sketches to three-dimensional models and marketing materials, producing very high-quality lifelike images, equivalent to good photographs or animated film. Input can be created at the workstation, scanned in, or received from CAD packages. TDImage also provides direct interfaces to several major CAD packages, including CAEDS, CATIA and PROFESSIONAL CADAM, without the need to pass via intermediate data formats such as IGES.

Output can be sent to graphics displays, video, film or other media. The software can run on single processor unix systems, but is also able to exploit the increased performance and enhanced capabilities of parallel machines, like the PVS, in the rendering and animation phases of TDImage execution. A crucial point to note is that, regardless of the specific application, the motive for employing such systems in the entertainment and advertising industries is the creation of pictures that elicit certain kinds of responses from the viewer (e.g. awe, wonder and curiosity).

These systems are unable to achieve this by themselves of course. They require a vital extra ingredient to be supplied by the user, namely creativity and aesthetic appreciation. Indeed, creative artists are especially adept at manipulating this sort of technology and are able to inject 'atmosphere' into the scenes and thereby stimulate some sort of emotional reaction from the viewer.

Archaeologist are just beginning to exploit the power of artistic stimulation too. Such a move is already projecting a new image of archaeology. In Germany, for instance, a project is underway to rebuild the once great baroque Frauenkirche of Dresden, which was destroyed in the aftermath of the firestorms that ravaged the city in 1945. The project is not being funded from the public purse. Instead financial support is being sought from the private sector and the general public. As part of a fund-raising campaign an award-winning animated tour of a photo realistic computer-generated model of the Frauenkirche, restored to its former glory, has be made to show sponsors and other donors what it is they are striving towards (Collins 1993; Collins et al 1994 forthcoming). A CAD reconstruction was built using Dassault System's' CATIA. (The input data were derived from a limited number of photographs and drawings, together with measurements taken from the surviving architectural elements). Once the CAD stage was completed, the advanced rendering of TDImage enabled photo realistic texture and illumination to be applied to the model. Additionally, the computer-generated church has been placed within a digital replica of the modern skyline to place the model in its fuller modern context. The animation is accompanied by music Johan Sebastaian Bach played on the Frauenkirche's organ!

The Frauenkirche project has all the elements for being an exemplar: it uses the latest high technology; the Frauenkirche was intrinsically a great work of architecture; the Frauenkirche has become an important symbol (of national unity); the ultimate goal of the project (i.e. the rebuilding of the Frauenkirche) is understood by the public; it is a very high profile project. The project has enormous potential to grab the public's imagination.

Already the Dresden animation have won acclaim at major graphics shows like Siggraph (which measures it audiences between 20,000–30,000) Eurographics and Imagina. Broadcasts on television will reach even large audiences. The image of archaeology that is being projected is one that is dynamic, hi-tech and, unashamedly, commercial. The impact of this image, however atypical it might be, is orders of magnitude stronger than many earlier archaeological visualisation projects ever achieved.

This should occasion little surprise as exposing audiences to such powerful pictures amounts to an advertising campaign. In the worlds of business and commerce, this sort of activity is regarded as market development.

More ambitious virtual reality projects involving the Frauenkirche are already underway and the existing material has already stimulated several even more ambitious proposals based on Roman Paris (B.N. Collins, pers. comm.). Clearly this is a far cry from our more usual channels for disseminating the results of research. If we look at the spread of visualisation projects a pattern is discernible. So far, the influence of visualisation projects appears to have been heavily reliant on personal contact. There seems to be a geographic or national axis, expressed as clusters of projects springing up in one country or region.

In Britain visualisation projects began cropping up in the first half of the 1980s starting with Woodwark and Bowyer's reconstruction of a Temple Precinct from Roman Bath and the Roman legionary bath houses at Caerleon (Woodwark 1991). These pioneering projects stimulated other projects in the city of Bath, such as the reconstruction of the Roman bath complex (Lavender et al 1992), and inspired a succession of visualisation projects elsewhere in the UK. These included the Saxon minster of Winchester (Reilly 1992a, 152–154), the Malew 18 keill (Reilly 1988, 187–216), the motte-and-bailey at Mathrafal (Arnold et al 1989), the Roman palace at Fishbourne (Cornforth & Davidson 1989), Kirkstall Abbey (Dew et al 1992), Furness Abbey and the Langcliffe limekilns (Wood & Chapman 1992). Elsewhere in Europe, we see other archaeology (heritage) experiments with visualisation technology.

In France, the CATIA-based models of the abbey of Saint-Guilhem-Le-Desert (Duriat et al 1990) were soon followed by CATIA-based reconstruction of the monastery of Cluny and the Roman baths of the same name in Paris (Luc Genevriez pers. comm.). Around the mediterranean littoral the modelling of ancient monuments is spreading rapidly.

In Italy the solid models of the Stabian baths of Pompeii (Gullini 1989) were soon followed by reconstruction models of now crumbling Roman aqueducts and the medieval church of S. Giovanni on Sardinia.

Classical Greek sites such as the Acropolis of Athens (Eiteljorg 1988) and Eleusis (Cornforth et al 1990) are heading the vanguard of visualisation projects in Greece.

In Egypt, visualisation is also enabling surrogate tours of monuments left by the Pharaohs: the pyramid of Pharaoh Pepi I at Saqqarah (Labrousse & Cornon 1991; Reilly 1992b) and the Great Temple at Karnak (Boccon-Gibod & Golvin 1990) have been the subjects of major visualisation projects. In Central America, the Xunantunich Archaeological Project in Belize is integrating visualisation studies within a much wider computer-assisted archaeological data exploration environment (Hetrick et al 1992).

Japan is also witnessing the rapid deployment of visualisation to portray archaeological interpretations of important sites. Here it is not only great imperial monuments, such as the palace at Nara (Morimoto & Motonaka 1993), Shogun castles (Miyata 1990) or the key-hole shaped tombs of the emperors (Ozawa 1993) that are being visualised.

The more rustic buildings of prehistoric villages, such as Yamada-Mizunomi and Yoshinogari have also been subjected to the similarly detailed programs of study (Ozawa & Kawai 1992; Ozawa 1993).

The methodological significance of the techniques deployed in these various projects has been elaborated elsewhere (Reilly 1992a). However, the same set of projects can be viewed along a completely different axis: namely the impact of such projects within the affected academic domains of study (e.g. Roman Studies). It has not been remarked before that the momentum towards visualisation is not a blanket phenomenon but, rather, tends to appear sporadically in particular study areas. Within disciplinary boundaries we can point to subjects which have been submitted to intensive investigation using visualisation. (The study of Roman and Romanesque architecture is perhaps the best example of the phenomenon). Penetrating the consciousness of a discipline has also relied on personal contact but sometimes, because of the nature of the subject studied (e.g. Roman architecture), transcends modern national boundaries, new ideas and approaches start gaining international currency.

Until now the dynamics by which the visualisation approach has been transmitted are not very subtle, and rely to a large extent on personal contact. Probably all the above-mentioned projects have been presented at seminars, conferences or other academic meetings where like-minded researchers exchange ideas and talk over problems. This reliance on contact and personal referent influence and power has probably meant that the range of subjects submitted to visual exploration has been relatively restricted. A cursorily inspection of the published material reveals the existence of an invisible school of archaeological data visual.

There is little point in amplifying all the details of this statement. Suffice it to say that a careful study of visualisation projects would show that many could be linked to a small number of practitioners, either directly (by looking at the names of authors on the project, publications and names in acknowledgements) or indirectly (by analysing the affiliations of authors, as well as those of the originators of the software and hardware employed in the projects). Not surprisingly, even if they don't actively collaborate on projects, most of this core group maintain links with each other by exchanging information and news by correspondence or at meetings.

One slightly unusual feature of the 'meeting of minds' in these invisible international schools of archaeological data visualises is a trade in animation and slides. The sharing of such graphics allows specialists to promote their ideas and techniques in much the same way as the more conventional practice of swooping books and offprints. As conduits for spreading ideas these channels of direct personal contact are of limited effectiveness because they rely on individuals establishing and developing one-on-one dialogues with other interested parties. This is a slow, time-consuming process which has, perhaps, encouraged an overly uniform attitude towards the aims, scope and potential of the approach in archaeology/heritage circles. The hold exerted by this small band of specialists on where and how visualisation techniques are adopted is being loosened by external factors. In particular, much larger audiences are being exposed to visualisations in circumstances where they experience an optical flow of information (and emotion), as static pictures or animation, without being subject to the academic discussion (both theoretical and technical) associated with the shaping and presentation of that specific set of information or application area.

A growing number of archaeological site visualisation projects have been broadcast locally, nationally and, in some instances, even internationally on television. Others are incorporated into museum exhibitions which have attracted many thousands of visitors. With no chaperones to instruct them, audiences that come into contact with such media are forced to respond solely to what they see and, typically, their response is not being tempered by the caveats or dogmas which previously would have been rehearsed in formal presentations by specialists.

As a way of influencing large numbers of people, exploiting visualisation and the media is a particularly powerful combination. It does, however, bring some new issues of principle in its wake.

Whose opinion takes precedence when producing visualisations for the media, the artistic director or the archaeological consultant? How do we balance academic credibility against artistic embellishments? On the one hand, the mass media provide the public with access to information about their heritage. On the other hand, the mass media also give those who shape our understanding of our heritage access to, and with it the opportunity to influence, huge numbers of people. Properly harnessed the custodians of our heritage have a marvellous channel to educate people. However, there is a big differences between responsible education, propaganda, entertainment and glamour. In many western countries archaeological- and heritage-based work has become increasingly commercialised. The temptation to produce something to catch the eye of the public, especially potential sponsors, means that as we approach the twenty-first century this issue of balancing intellectual and commercial considerations will grow in importance, and may well cause friction and malcontent amongst the ranks of the custodians of our heritage if it is not properly addressed.

Conclusions

Clearly we are witnessing the convergence of what are presently several distinctive approaches to data analysis into a single integrated and general purpose environment for data exploration. Visualisation is currently one fashionable approach to data analysis which has grown from a union of graphics, imaging and modelling. It continues to develop and has emerged as a crucial element in a new way of representing and exploring the world through so-called virtual realities. In extending the boundaries of what are thought to be the legitimate specialist and technical concerns of the discipline of visualisation, the demarcation between visualisation and other data exploration and presentation approaches has become extremely blurred. For instance, computer vision which, in many ways, can be regarded as an extension of pattern recognition and imaging into three or more dimensions shares many common goals with visualisation (e.g. segmentation algorithms).

A similar sort of synergy can be seen in the application areas to which these technologies are applied. We may note, for example, that understanding three-dimensional data collected using prospecting devices such as the increasingly popular Ground Pulsing Radar is remarkably similar to the challenge faced by geologists analysing seismic surveys and surgeons planning operations using radiography can harness these visualisation and segmentation procedures.

Formal quantitative and statistical approaches have been successfully married with databases as well as cartographic and imaging technologies in Geographic (or GeoScientific) Information Systems. Software vendors are building bridges between several of the most popular GIS systems to both CAD (e.g. ESRI's ArcINFO and Auto desk's Auto CAD) and, now, visualisation packages (e.g. ArcINFO and IBM Data Explorer). As a young discipline, visualisation was regarded as a worthy end to a project its own right. As the discipline has matured, access to the skills and technology necessary to adapt, develop and apply the approach has become more widely available, and we can now see it as merely a means to and end. So while continuing to become functionally richer and more sophisticated it has begun to be absorbed into the larger mass of data exploration approaches.

At one level what we are witnessing is simply the latest stage of a long-standing process of technological development and intellectual cross-fertilisation brought about by the adoption and adaptation of new methods.

At another level, however, we sense more fundamental changes about the role and standing or archaeology and our heritage. Of late we have begun to detect significant moves to make archaeology more glamorous and more entertaining in an increasingly competitive and commercial environment. In the midst of these changes visualisation is providing wider access to certain forms of information about Sites and Monuments together with insights into complex data sets, but, at the same time, is allowing new groups access to the process of shaping the information that is disseminated.

In addition to the archaeologist, the entrepreneur and the creative artist are now wielding considerable influence over the format and delivery of information about the past. It is essential that those with a vested interest in archaeology, and heritage more generally, recognise and discuss the implications of the changing influences on the focus and nature of archaeological discourse through pictures.

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Data analyses and interpretations based on information content in practical and theoretical archaeology

Andrea Vaday–Ildikó Fejes***
*Archaeological Institute of the HAS
**Hungarian National Museum, Dept. of Information

Archaeologists work with well defined, concrete materials. A number of objective and subjective factors, however, complicate the verification and use of abstract conclusions. In practice, no widely applicable, sophisticated system has been devised which could provide a joint platform for the detailed and multi-faceted evaluation as well as interpretation of the entire excavated material.

The dominance of subjective elements is still characteristic of archaeological research. A very important objective factor, the assessment, recording, and quantification of information value is missing. This makes concrete comparative analyses impossible. Consequently, the more complicated the conclusions the more interpretations deviate from the actual media of interpretation.

The introduction and evaluation of information value points beyond the in-depth analysis of information. Data recorded and processed this way would be based on standardised criteria whether they are obtained by first hand observation of the artifact or derived from publications. This method would result in the development of realistic, concrete and controllable models. The assessment of information value would also facilitate defining the concept of reference materials in a concrete and more objective way.

Both the problems and proposed solutions were demonstrated using Roman Period materials from the Barbaricum.

The following problems were addressed:

1. the information value of written sources
2. the information value of archaeological materials
3. synchrony and asynchrony between written and archaeological sources
4. the information value of archaeological materials by origin
5. using such data in the identification of ethnic groups and trading links
6. local and regional projections made at various resolutions
7. the information value of excavations; the evaluation of archaeological sites on the basis of information content recovered
8. the interpretation of excavation data using objective and subjective criteria
9. the information value of material interpretations and typological systems; the use of parallels in evaluation, analyses and drawing conclusions
10. the determination, definition and use of reference materials
11. the development and application of models
12. the interpretation of data from Hungarian publications
13. the interpretation of data from the international literature
14. the relevance of information in the literature to reconstruction

Hierarchical typological systems as a basis of computer analyses

István Zalai-Gaál
Archaeological Institute of the HAS

Basic problems of prehistoric archaeology, among others, questions of typology and chronology cannot be solved using computer programs alone.

In the beginning, these problems were treated exclusively by typological classification. Good examples of this approach can be found in "traditional" German prehistoric research where, e.g., periodisation of the Neolithic was realised basically on specific formal features of the pottery finds. This approach means one of the extremities in Central European Neolithic research.

The other extremity is represented by the use of computers for archaeological interpretations. In this case the problems encountered in course of excavations and archaeological studies were expected to be solved by computer programs.

Experiences of the author in the so-called "Saarbrücken school of archaeology" and research result support the hypothesis that neither the pure typological method, nor the mechanical application of computers can be fully adequate in prehistoric analyses.

Namely, it makes a lot of difference what is actually fed in a database management system or a serration program. In our actual example, the pottery finds of the Mórágy-Tűzkődomb Late Neolithic graves (Lengyel culture) are presented where a hierarchical typological system was established which could be used as suitable basis for the analysis of further connections.

The serration analysis was performed by the help of the serration program developed by A. Suhajda. The same method, i.e., serration of hierarchical typological entities can be used not only for pottery but also for any other conceivable or observable archaeological features.

Seriation and its Application in Archeological Research

Attila Suhajda
Hungarian National Museum, Dept. of Information

This essay deals with Seriation processes, the areas where these processes can be used and the criteria for their use. The reader will be introduced to the more important Seriation applications as well as our own Seriation programme.

Seriation Definition

All methods for the chronological ordering of objects (e.g.: graves) at any one site which are based on the comparison among artifact are referred to simply as Seriation processes. Characteristic of all these methods is that only the finds belonging to any one particular object, or other characteristics of the object are used to determine chronology, whereas statigraphic information is not used at all.

Classification of Statistical

Statistical methods can be divided into two major groups

1. Descriptive Statistics

Methods suitable for the Visual presentation of the connections between Information and the examined objects belong to this category (e.g.: Harris Matrix, Histogram, etc.)

2. Inferential Statistics

A group of complex statistics for the examination of particular archeological theories. It is a common characteristic of all that they demand a high level of computing and are capable of two or more variable, simultaneous examinations. Within this category the Seriation belongs amongst the "ordering" statistics, whereas the Cluster Analysis (examination of interrelations between artifacts) belongs rather to the "Classifying" statistics group.

At this stage it is important to clearly define two terms. The Seriation "Unit" or "Object" is the term given to those archaeological objects which occur on an archaeological site (e.g.: graves, houses). Seriation "Types" is a term defining the objects-types (e.g.: Pottery) which occur on an archaeological site and which assist in the chronological ordering of the Seriation "Units".

Typical applications for Seriation include the analysis of Pottery finds, the chronology of Grave-sites or the ordering of groups of artifacts which occur in great numbers of any site. Seriation orders exclusively on the basis comparison between objects.

As we have already mentioned, this process almost always employed for the establishment of chronological order. Chronological question of this type include the determining of chronology of cemeteries or the dates of manufactured artifact types (fibulae,swords) from any one object (grave).

Chronological determination raises numerous problem. Firs of all we are faced with the question - What factors make an ordering process chronological? That is, how we chose our examination guidelines in such a way that they produce a chronological Order.

According to I. Rouse, any Seriation produced order requires the fulfillment of the following minimum criteria for it to be chronological.

1. The Seriation "Units" should originate from one site.
2. The Seriation "Units" should belong to the same culture.
3. The characteristics of the selected Seriation "Units" should be cultural, and therefore potentially chronological in nature.

Satisfaction of these criteria in itself is not sufficient for the "Unit" order to be chronological order. The creation of an ideal classification system especially important considering the fact that even a small group of Seriation "units" can be ordered in surprisingly different ways. For example, 10 objects might represents approx. 3.000.000 potential orders.

Guidelines for the selection of Seriation "Types"

It is most important that objects to be serialized be classified uniformly. Without the employment of traditional typological procedures for the classification of objects, this system is unable to produce reliable findings. It is upon this now classified "mound" of object that Seriation procedure can operate. In a typological system it is also possible, for example, the case of cemeteries for "Burial-rites" or other habits associated with the burials to be components of Seriation. These are all characteristics of graves which can be "measured".

It is important to note, that any inconsistency in the classification of the artifact can greatly distorts of the results.

It is worthwhile omitting from the Seriation procedure those artifacts types which occur either very rarely or extremely frequently, as these can often give false result also. Artifacts which occur in relatively small numbers across a lengthy are useless from chronological viewpoint. It is also practical to omit those types which occur in objects containing a great number of artifact types. It is less common for any given type to have been manufactured in large numbers for short period of time. This can prove to be an important chronological fact.

The Seriation Algorithm

Chronological ordering is base upon the assumption that artifacts are manufactured in particular time intervals. Thorough the use of these particular intervals we are able to place the objects (graves) in which these artifacts occur into chronological order.

Those objects (e.g.: graves) within which a particular artifact type occurs less frequently may exist in time prior or post those objects in which this artifacts type most frequently. The task is for these time-intervals to become as close to each other possible, in order to gain an exact chronological order. This requires complex ordering process, which is essentially the task of the Seriation Procedure.

The basis of the examination is the so called "Occurrence" Matrix. Its simplest form in the case of a cemetery is a table whose lines represents the various objects (i.e.:graves) and the columns represents the artifact types which can be found at the site. The occurrence of any type in any one object recorded by an "x" in the appropriate position (**Table 1**.).

The "Similarity" Matrix can be calculated from the "Occurrence" Matrix. This Matrix expresses the similarities between objects (e.g.: graves) with the assistance of the items to be found in them. This values frequently expressed as a %.

All Seriation Procedures begin from one or the other of these two matrix types. The procedures are of two basic types. One transforms the matrix (orders the lines and columns), whilst the other arrives at the desired order employing a multidimensional scaling method. This article shall deal in more detail with a simpler transformation method which works from an "Occurrence" Matrix.

The initial "Occurrence" Matrix is of the following order.

type/ grave no.	A1b	A2b	B1a	C1a	C1b	C2b
1.	x	x			x	
2.			x	x		
3.	x			x		x
4.	x		x		x	
5.		x		x		
6.		x			x	x
7.	x	x		x		
8.	x		x	x	x	
9.	x	x			x	
10.			x			x

Table 1.

The essence of the procedure is as follows

Selects the type which occurs in the greatest number of graves, then examining in which graves these types occur. The artifact types of graves selected in this way are then collected and the next most frequently occurring of these is selected. The procedure observes which graves this types occurring of these is selected. The procedure observes which graves this type occurs in. Should a grave or an artifact type appear at this stage then these are also added to the list. And so forth...

The matrix is converted according to the results, that is, the first type will be the most frequently occurring, the second the next most frequent, whilst the first grave will be that in which the most types can be found, and so on...

It is important to note that only those matrixes can serialized, in which more than one artifact occurs in the various graves. An almost empty matrix cannot be serialized!

Upon the completion of the Seriation Procedure, **Table 1.** appears as follows:

type/ grave no.	A1b	A2b	C1b	C1a	C2b	B1a
1.	x	x	x			
3.	x			x	x	
4.	x		x			x
7.	x	x	x			
8.	x		x	x		x
9.	x	x	x			
5.		x		x		
6.		x	x		x	
2.				x		x
10.					x	x

Table 2.

It can be observed that the order of the lines and columns has altered in correspondence with the above description. The order of the graves is the probable chronological order.

It is important to stress that this is a relative order, that is, we are unsure which end represents the oldest grave. It follows that in all cases the archeologist's interpretation of the Seriation results is called for. Only in conjunction with supplementary examinations such as the C_{14} does this result become useful.

Weighted Seriation

It can occur that a particular type which is given preference by the archeologist does not occur the most frequently. In such instances this „Main" type can be manually defined in the first column, thus influencing the final result.

The result can be more subtly influenced by the weighting of the various types. Here the individual types are weighted according to their lesser or greater chronological importance, through the application of a multiplication factor ranging between 0 and 1 (see example below).

Take, for example, that the "Alb" type is chronologically less important than the most important "C1b" period defining type. In this instance the "A1b" type receives a factor of 0.5, whilst the "C1b" type receives a factor of 1.

Further Seriation Methods

Kendall elaborated a method for resolving the Seriation problem (determination of Chronological Order) which remains one the best even today. Into the simple selective ordering he incorporated another statistical procedure, the multi-dimensional scaling method, thus arriving at surprisingly good results.

This method was employed by Kendall for the examination of 60 graves in the Münsingen Cemetery in 1971. This examination produced results closely approximating those of the traditional archeological procedures, thus proving the correctness of this method, considering the Münsingen Cemetery represents an ideal example of chronology.

Several Important Seriation Projects

In 1899 W. M. Flinders Petrie became the first to use Seriation Procedures for determining chronology in cemeteries. 900 Egyptian graves were categorized into 18 groups of 50 graves each, and then each was manually computed into chronological order.

In 1968 Hodson examined 30 La téne fibulae in the Münsing Cemetery. The sample, as can be seen, was very small, useful only for experimental purposes. 13 dimensional details of the fibulae were entered and the resulting information recorded in tables. The basis of this Seriation was the dimensions of the artifacts.

On the same site Kendall examined 70 metal artifacts originating from 59 graves. Here he used for the first time the so-called "Horse-shoe" method, which employed a multi-dimensional scaling of the Seriation procedure.

The largest Seriation project belongs to K. Goldmann, who ordered 790 South-Eastern, Central and Eastern European Bronze artifacts into 404 types. During the ordering statigraphic data was also used.

Seriation Programs

Statistical Programme-packages have also been prepared especially for archeological use. The most important and widely knows is BASP (The Bonn Archaeological Statistics Package), produced by Irwin Schollar and his team. Amongst the many mathematical procedures an excellent Seriation algorithm can also be found.
The latest edition of the programme includes the following analytical possibilities:

- correspondence analysis
- cluster analysis
- Seriation
- Simulation
- social status analysis

The Programme-package also has numerous supplementary elements. For example, the programme is able to check if there are distorting factors amongst the Seriation types prior to the beginning of the programme.

This programme is recommended for those archeologists who wish to employ mathematical procedures in their research.

Together with István Gaál I have produced a Seriation programme which was used for the examination of Neolithic cemeteries in the Dél-dunántúli region. This program uses the "Occurrence" matrix and the Primary Element Selective Ordering method as described in detail above. It allows for the selection of a dominant type, thus influencing the entire result. The programme handles several cemeteries at once and is capable of converting dBase data into "Occurrence" matrix form. From this matrix statistical data is produced according to type and object. Both the initial and the resultant matrix can be printed in varying sizes.

Conclusion

It is practical to employ Seriation methods for the determination of chronological order in the absence of statigraphic or other traditional archeological data from the site in question. Another use is for the proving or rejection of various archeological theories. Basing chronological judgments solely on these methods is not advisable. Only through the use of additional procedures, for example the C14 chronology test, can the resulting chronology be considered, at the most, equivalent to the results of these tests.

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Documentation and description method of Roman amphorae, typological analyses with the application of mathematical statistics

Tamás Bezeczky
Informatical Research Group of the Hungarian National Museum

The unification of the description of various objects was already exposed in archaeology for a long time. Essential progress in this field, however, was achieved only with the application of computers. Since the beginning of the fifties, a number of conferences were consecrated to relevant topics. As a consequence of these, the collaboration of mathematicians and archaeologists resulted in valuable achievements. Attention was paid to the evaluation of objects occurring in large number. Formerly these data were disregarded because these object in themselves had little interest and their large masses could not be adequately elaborated with traditional methods. Technical development of computers and the improvements in program systems made it possible in a short time to handle archaeological problems in a mathematical way, modelling them and treat the data by different data management techniques. Possibly the biggest problem for the preparation of archaeological documentation has always been the formation of a unified description system. It is well known that the same object is often described in different ways, even more, it is termed different ways in many instances. By the utilisation of computers it was necessary to use a highly formalised description system in the positive sense. For ceramic finds, a basic description method was elaborated by J.C. Garden with the help of analytical codes. The description of amphora forms was amply treated in technical literature. This is the basis of traditional typology as well. Supposing that the form of the object convey important features of the object, morphological studies aim at revealing functional and genetically connections. The description system incorporates the morphological, technological, archaeological, epigraphic and petrographical data on the amphorae. In course of a morphological description the metrical data and relevant ratios represent a data set which can be evaluated from typological and chronological aspects as well, thus they can be further analysed by computer assisted statistical methods (factor analysis, cluster analysis). In our experience, the methods applied can be equally used for the study of other groups of objects. With further extension of the method, fragments can also be fruitfully analysed

To date, when fashion dictates the application of large databases, we are opt to forget about the object of which these databases are built up.

This paper will present a documentation system elaborated in the South French research centre of the CNRS (Garden 1967; Hamon and Hesnard 1977; Guénoche and Tchernia 1977), which is completed with petrologic analysis methods developed in the University of Southampton (Peacock 1970; Peacock 1977; Peacock and Williams 1986). Finally, I will describe the computer programs made for these methods in the Hungarian National Museum (Bezeczky-Kerékfy-Rónyai 1987; Bezecky and Rezi Kató 1991). We shall tackle the description method of Roman storage amphorae, which is suitable for the documentation of all ceramic types.

Documentation occupies an important place in the analysis of Roman amphorae. Prior to its preparation, the object to be described has to be defined. In the case of the amphorae it is a two handled vessel used in Antiquity for trading purposes, storage and transportation (Fig. 1). The vessels furnish information not only about the food they kept but also about the place where they had been made and about the persons who used them. A good illustration of the features of the Roman containers can be gained with the analysis of the amphora depot (Monte Testaccio) in the centre of Rome (Rodriguez-Almeida 1984), where the fragments of about 53 million, mostly Hispanian amphorae were uncovered in one site. Even here, in the northern province of the empire (Noricum, Pannonia), thousands of amphora finds have been counted. This is a find material that occurs in great masses and the study of which is an integrated part of research in all the modern states that were funded in the territory of the Roman Empire. That is why a documentation based on mutual bases is required to enable the comparison of objects in joint research.

Description method

Documentation is composed of a text part with descriptions and a graphic/picture part. The problem is that the terms of natural language and not unilateral, the same object may be described differently by various authors. That is the reason of the use of graphic and picture illustration.

The applied description contains morphological, epigraphic, technical, petrologic, archaeological and historical data.

Morphology

It contains the rules and generally accepted conventions that specialists usually use for analysis:

- the orientation of the object, which allows that the object would always be described in the same position and which is always used in publications (Fig. 2.1),
- segmentation of the profile, which helps to identify a certain amount points and sections in the profile of the vessel.
- characterisation of the parts defined by segmentation with demotions as shape, vaulting, extension.

The morphological analysis follows the above policy.

1. Orientation

We can get the profile of the amphora with cutting the vertically set object with a plane that crosses the points of junction of the handles. It can be completed with the depiction of the section of the handles (measured at half of the height). Besides, if it is possible, the profile of the rim should be presented in a larger scale.

2. Segmentation

In archaeological practice the profile of an amphora is characterised through the elements of the vaulted line, e.g. belly, shoulder etc. Consequently, these parts should exactly be defined for a unilateral understanding. The names of the parts do not change, their definition, however has not been unambiguous. Two different authors do not use the same terms. One holds that belly is the part under the shoulder while according to another the belly comprises the shoulder. These segments will be the names of the parts of the amphora and they will further be subdivided.

a) **main parts of the amphora**
The first thing to be recognised in the profile is the body of the amphora, then the attached parts: the handles and the stopper. The body is divided into two large parts: the belly which bears the real function of storage. This is where the other parts are attached to. The bottom is attached to the lower part of the belly, the amphora is set on this part. The neck of the amphora is attached to the upper part of the belly. Sometimes it may be missing when the rim is attached directly to the belly.

The vessel has two handles (coming from the word amphora). It is sufficient to describe just one of them, its section, however, should always be given.

The stopper may be described independent or placed in the neck of the amphora.

b) **subparts**
All parts, except for the neck, are divided into subparts:
- the belly of the vessel is usually divided into two parts, lower and upper parts, independent of the shape of the belly (Fig. 3.1).
- the base, if it displays a single, unbroken vault is not further divided (Fig. 3.2). In other cases, it is divided into lateral and basal parts.
- the rim is the only part where the inner side of the profile has to be examined. It can be divided into two parts: outer and inner sides (Fig. 3.3). Their position on the profile are defined by the rules of segmentation.
- the handle is also divided into two parts, lower and upper ones (Fig. 3.4).

c) **junctions and segmentation rules**
Junctions are defined as places of separation of two parts. There are junctions between all the above described parts. The problem of segmentation is where these points are in the profile. If these points are defined, all parts of the amphora are defined (Fig. 3.5). The problem is that archaeological practice differentiated large zones on the profile. There are hardly discernible demarcation lines between the neck and the belly of the amphora. They do not have a constant geometric definition. For the definition of the junction, there are two possibilities. Either there is a steep peak or a deep groove between the two parts on the vault, in which case junction is obvious, or, when there are no sharp changes in the vault, the junction is at the inflection point between the two parts (Fig. 3.7-8).

A few more conventions should be added.
- At the junction of the rim and the neck (sometimes belly) (Fig. 3.5)
- Both sides of the rim continue the line of the neck: the junction is conventionally at the upper third of the neck.
- Only one side of the rim continues in the line of the neck: the junction is at the point where the wall starts thinning towards the neck.
- Both sides of the rim bulge: the junction is at the same point as above.
- The sides of the rime break as compared to the vertical axis: the junction is at the point of the break.
- At the belly, if the vault breaks three times, the junction between the upper and lower part is at the second break from below.

The profile can always be defined through the alteration or relative vault from the vertical axis. If the profile changes within the parts of the vessel, it must be noted in scripture.

The codes, expressing the shape of the profile were first applied for the description of ceramics by J.C.Gardin (1967). The junctions of the main parts can also best be characterised with Gardin's codes (1967) (Fig. 4).

Measurements of the amphora

The measurements indicated the relative size of the object (Fig. 2.1). For all parts, the height at the greatest breath should be given together with the height and relative breadth connections of the various parts (Fig. 2.2-3).

The mathematical analysis of the ratios gained from the measurements was made by A. Guénoche and A. Tchernia (1977) who found that within one type (Dressel 20), the data can be evaluated in chronological and typological groups as well. At the analysis of another amphora group, A. Hesnard and A. Guénoche (1983) could discern the items of various production centres even in their fragments with the help of the applied method.

It should be noted that for the drawing of the profile and the taking of measurements, a three dimensional drawing program was developed together with the Graphisoft Kft (a variety of Archi-Cad run on IBM PC, Bezecky - Rezi Kató 1991), where the above measurements can be read from the drawings (Note: the content and the weight of the vessel can naturally be calculated (Fig. 5). The significance of the program lies in the fact that a similar program did not exist for a PC in 1987). Another program (MARCH) is suitable for the formation of typological groups with using mathematical statistical methods. (On the BMDP variety for large IBM Bezeczky–Kerékfy–Rónyai 1987). Our aim was to shift the typological analysis, which thus far was made on an experimental basis, to a more exact, quantitative base. We tried to introduce such well measurable, well defined features that grasp the information in the geometric and shape of the amphorae much better. The result was the choice of a suitable model. It was reached with the archaeological evaluation of mathematical (computerised) results.

Returning to the documentation, the description will contain special features which might have been created during production, e.g. finger prints, grooves, cuts etc.

Technical description

This contains observations concerning the raw material, the ceramics and the technique of production.

The colour of the ceramics is given according to a colour scale: Munsell Soil Colour Charts (Baltimore, Maryland, 1975).

From among the petrologic analyses, microscopy helps the definition of the construction of the material (Fig. 5.1), X-ray diffraction tells about the firing temperature and the raw material used during production (Fig. 5.2; Józsa-Szakmány-Iváncsics-Weiszburg 1987 and Józsa-Szakmány-Weiszburg-Sauer 1993). In a few cases, neutron activation analysis may demonstrate trace elements of rare metals. These scientific methods complete each other and provide additional and precise data about the workshop where they were made. (In an analysis in process, about 500 features of an amphora are defined. The workshop, which functioned on the Istrian Peninsula in the 1st c. A.D., was owned by C. Laecanius Bassus, senator. The amphorae were well known in Cisalpina, Noricum and Pannonia.)

The next chapter of documentation is epigraphy.

The epigraphic indications on the vessels (stamps and inscriptions) tell about the origin, type, trade and the name of the producer of the food stored in them.

1. The stamps were stamped in the amphora before firing. According to the various vessel types, they were placed on the rim, the body, the handle, sometimes the bottom. Usually, they contain the name of the land owner where the potter's workshop (figlina) functioned. Sometimes, it may be supposed that the name of the potter, or the villicus (steward) was indicated on the stamps (Fig. 6.1-13).

2. Two types of inscriptions are known. One was painted (titulus pictus) (Fig. 6.14-16), the other was encised with some sharp object (grafitto) on the surface of the vessels. They tell about the content of the amphora (Fig. 6.14-15), its weight (Å and Ó), quality, way of production, perhaps place, date, the tradesmen - ship owners (ß), date of customs clearance, the name of the customs officer (_). Sometimes, it may also refer to the arrival of the ship or its position in a depository (horreum).

Observations concerning the object can be made placed among the archaeological data (site, section, layer, identification data etc.).

The descriptive and picture/graphic information all get into one database. On present technical level, they can be treated together on the screen, to which a video system can be attached in the HNM. In order that all the elements of the above system work appropriately, a lot of effort is yet to be done. Still in the past 16 years, the development of an up-to-date informatic system has been started (see paper by G. Rezi Kató). The method can freely be adapted to the documentation of other groups of objects.

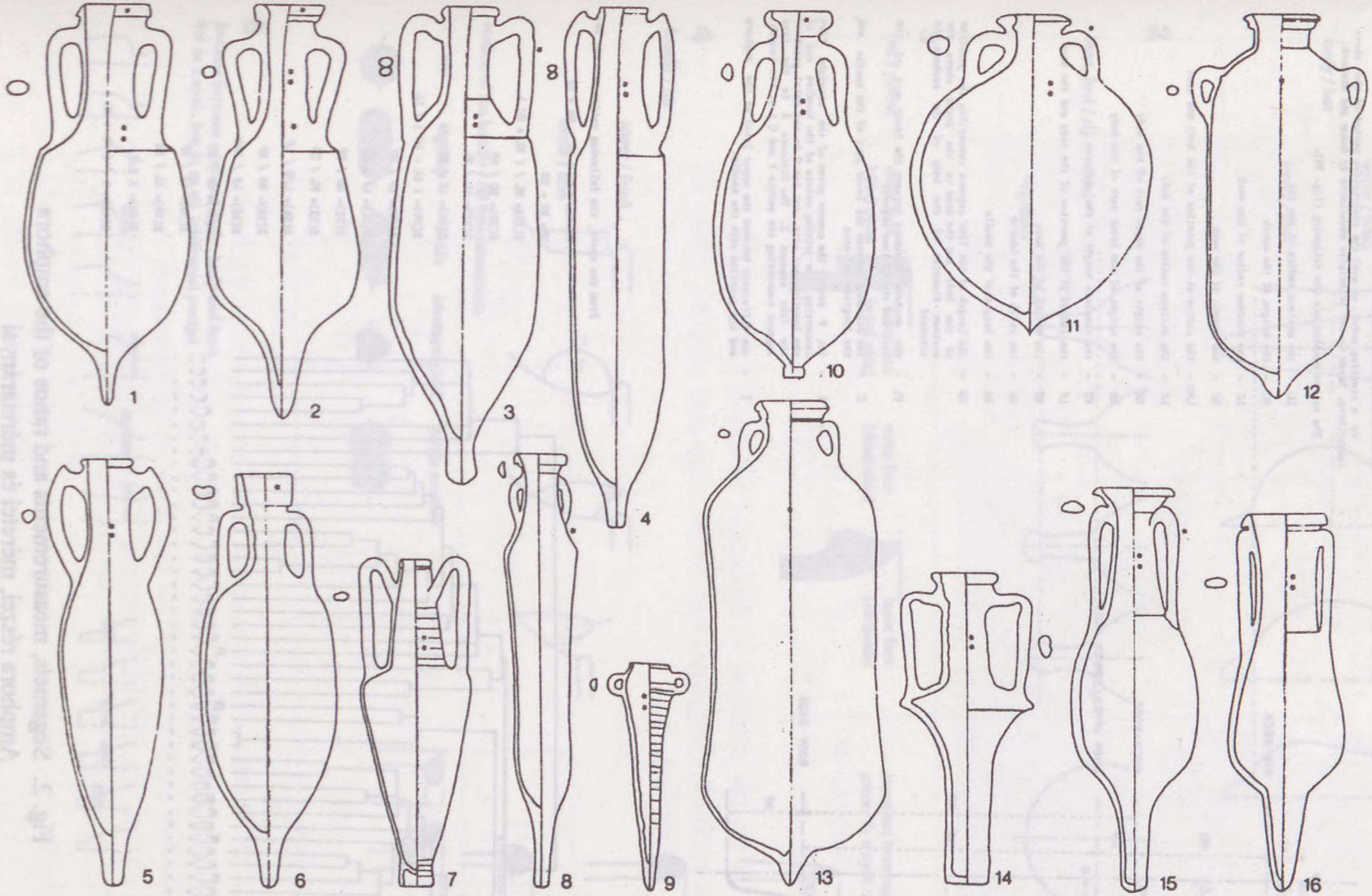
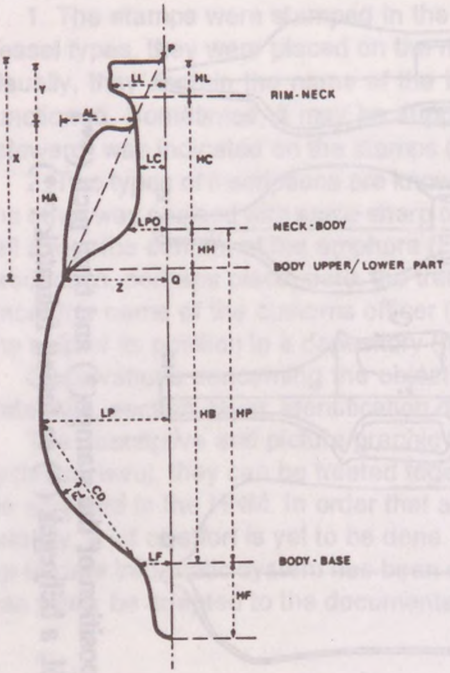


Fig. 1. Roman amphorae from Pannonia, position of the stamps(*) and tituli picti (**)
Római amphora leletek Pannoniából, a bélyegek (*) és festett feliratok (**) jelölésével

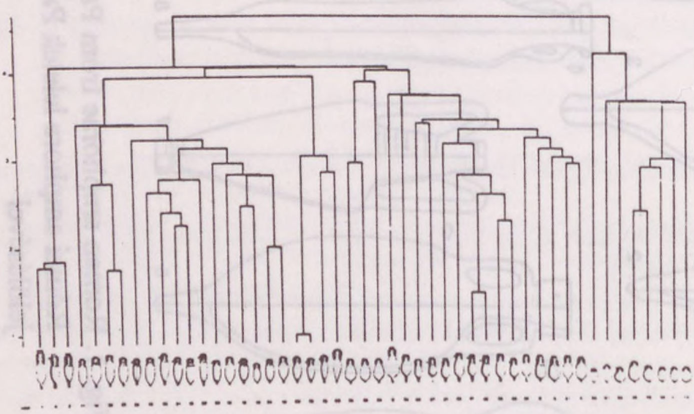


The Guénoche and Tchernia method

As a starting point, we used the descriptive method of the above researchers, based on the principles enunciated by Hamon and Hesnard.

The values adopted are the following (fig. 39).

- LL - the maximum radius of the rim
- HL - the height of the mouth
- LC - the minimum radius of the neck
- HC - the height of the neck
- LPO - the radius at the junction of the body and neck
- LP - the maximum radius of the body
- HH - the height of the upper part of the body
- HB - the height of the lower part of the body
- HT - the complete height of the amphorae
- LF - the radius at the junction of the body and the base
- HF - the height of the base
- AL - the width of the handle
- HA - the height of the handle
- CD - the length of the line segment connecting the junction of the body and the base to the point where the maximum diameter of the body of the amphora is attained
- FL - the maximum distance between the lower part of the body and the CD line segment
- Z - the distance between the lower part of the handle and the longitudinal axis
- X - let P denote the common point of the straight line connecting the joining points of the handles and of the longitudinal axis, and let Q be the axial point of the line segment Z. The distance X is the line segment connecting the points P and Q i.e. its length
- Y - the difference between the upper level of the amphora and the junction with the handle.



From the above, the following ratios are set up:

HT= HL + HC + HH + HB + HF

HP= HH + HB

X(25)= HL / (HL + HC)

X(26)= HC / HP

X(27)= LL / HL

X(28)= LC / HC

X(29)= (LL - LC) / LL

X(30)= LP / HT

X(31)= LP / HP

X(32)= HB / HP

X(33)= FL / CD

X(34)= LPO / LP

X(35)= HH / HP

X(36)= LF / LPO

X(37)= HF / HT

X(38)= LF / HF

X(39)= AL / HA

X(40)= Z / X

X(41)= Y / (HL + HC)

Fig. 2. Segemets, measurements and ratios of the amphora
Amphora részei, méretei és méretarányai

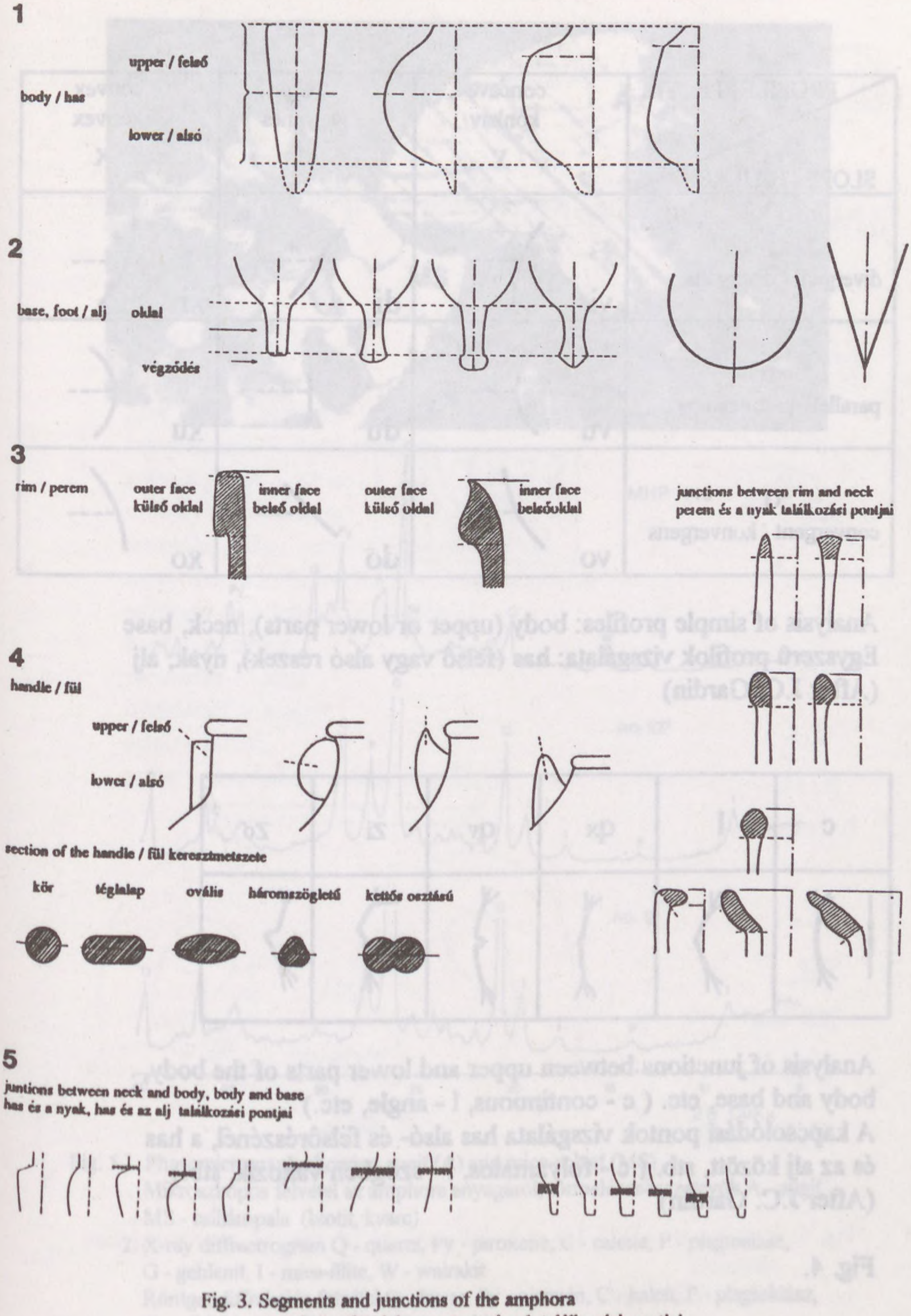
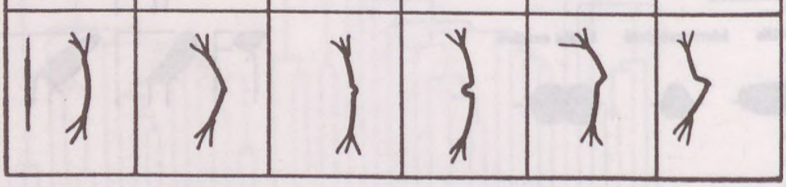


Fig. 3. Segments and junctions of the amphora
Amphora részei és az egyes részek találkozási pontjai

PROFILE / PROFIL — SLOPE / HAJLÁS	concave konkáv v	straight egyenes d	convex konvex x
i divergent / divergens	vi	di	xi
u parallel / párhuzamos	vu	du	xu
o convergent / konvergens	vo	do	xo

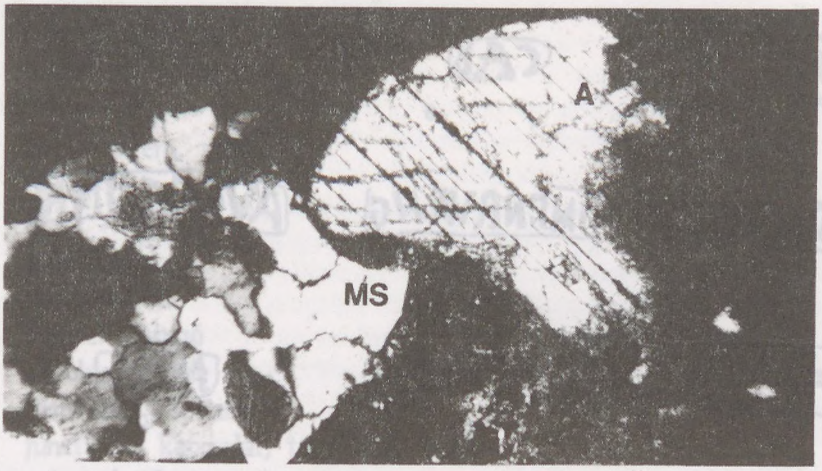
Analysis of simple profiles: body (upper or lower parts), neck, base
Egyszerû profilok vizsgálata: has (felsô vagy alsó részek), nyak, alj
(After J.C. Gardin)

c	l	qx	qv	Zi	Zo



Analysis of junctions between upper and lower parts of the body, body and base, etc. (c - continuous, l - angle, etc.)
A kapcsolódási pontok vizsgálata has alsó- és felsôrészénél, a has és az alj között, stb. (c - folyamatos, l - szögben változik, stb.)
(After J.C. Gardin)

Fig. 4.



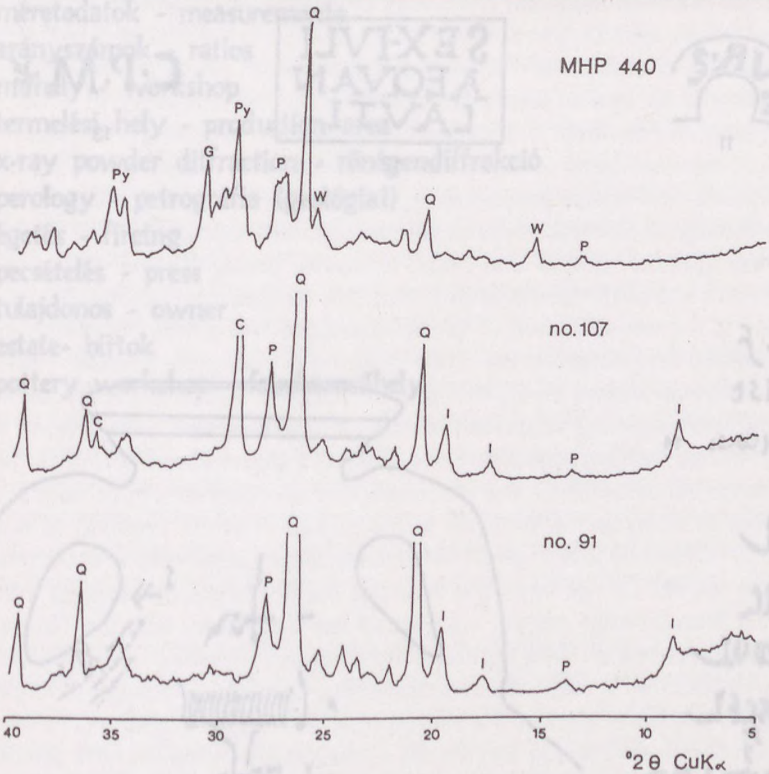


Fig. 5.1 Photomicrograph showing augit (A) and mica-schist (MS)
Mikroszkópos felvétel az amphora anyagáról, törmelékesösszetevök A - augit, MS - csillámpala (biotit, kvarc)
2. X-ray diffractrogram Q - quartz, Py - piroxene, C - calcite, P - plagioclase, G - gehlenit, I - mica-illite, W - wairakit
Röntgendiffrakciós felvétel Q - kvarc, Py piroxén, C kalcit, P - plagioklász, G - géhlenit, I - csillám-illit, W - wairakit

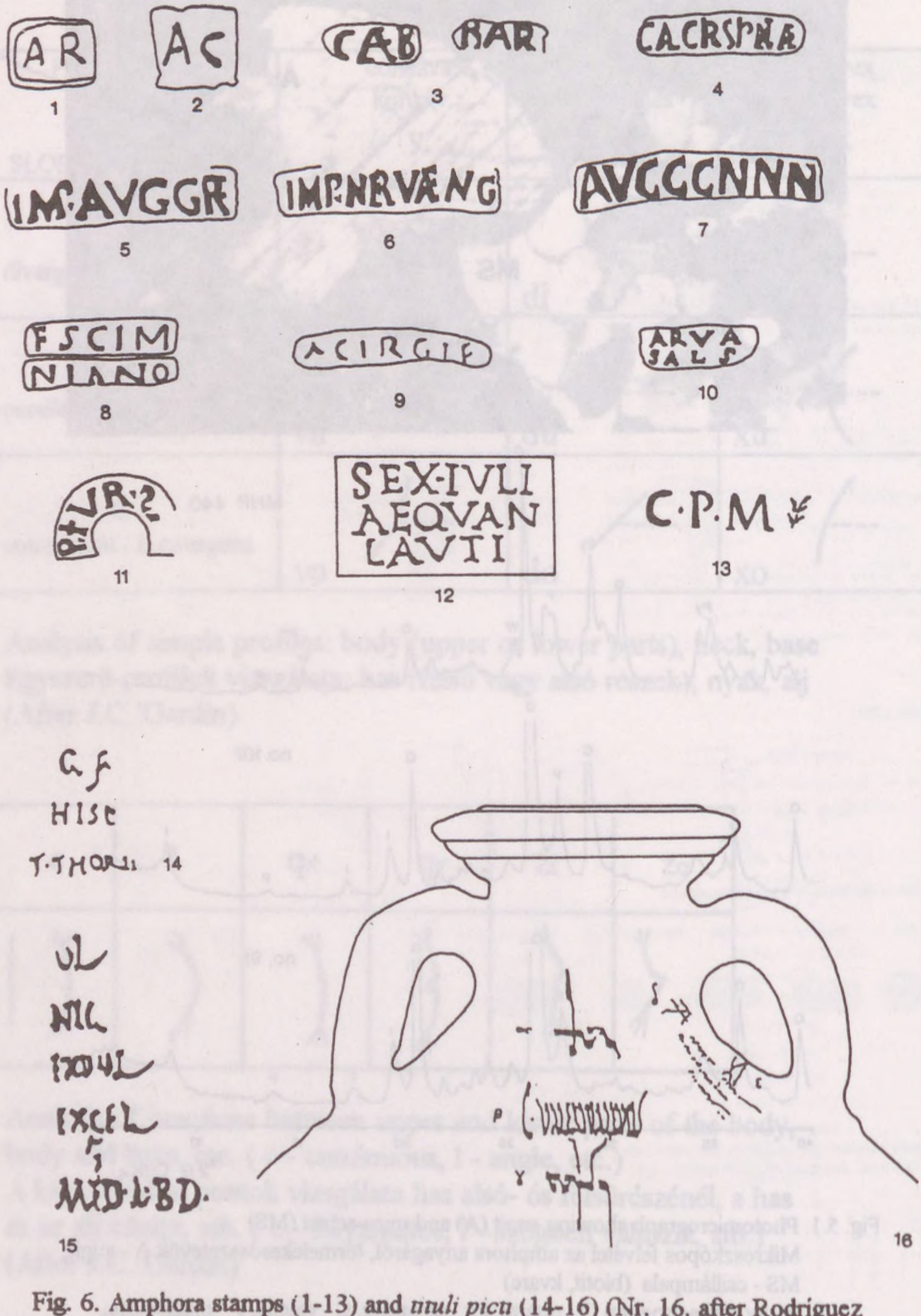


Fig. 6. Amphora stamps (1-13) and *tituli picti* (14-16) (Nr. 16. after Rodriguez Almeida)
Amphora bélyegek (1-13) és festett feliratok (14-16)

Fontosabb kifejezések

rim - perem, szájperem
neck - has
body - has
base - alj
handle - fül
stopper - dugó
shoulder - váll
hispaniai - Spanish
junction - kapcsolat, találkozási pont
méretadatok - measurements
arányszámok - ratios
műhely - workshop
termelési hely - production area
x-ray powder diffraction - röntgendiffrakció
perology - petrográfia (geológia?)
égetés - fireing
pecsételés - press
tulajdonos - owner
estate- birtok
pottery workshop - fazekasműhely

Computer project of the Hungarian National Museum 1982–1993

Gábor Rezi Kató
Hungarian National Museum
Department of Archaeology

Motto: "Complex systems developed from nothing will never work and cannot be put to action with any kind of stitching. The whole must be started anew from a simple, working system."
MURPHY 16th thesis on system semantics

ABSTRACT

The Hungarian National Museum started its computer development program among the first ones, a decade ago. Due to the lack of actual means the first step of the program was the modernisation of traditional means of documentation (description forms) and the preparatory work with an eye on future computerisation (terminology). In 1986, in frames of an OTKA (National Foundation of Scientific Research) project the Museum was able to obtain the first minimal items of software and hardware. A program was prepared for two- and three dimensional image presentation, a statistical evaluating program and a Clipper-based archaeological oriented data base management application (MIDAS). The development of informatical means and tools, however, brought about better tools than we could achieve in our own development, thus the Hungarian National Museum changed for DataEase in the development of its own database. As a result of continuous development in hardware and software we could build up an integrated system where our aims seem more realistic. Based on RDBM and an adapted document archivation system we have possibility of handling visual information, complemented with a video database. In 1991, an American system organisator, N. Statland, elaborated a four-year project for the Hungarian National Museum for the introduction of an integrated informatical system. This project stated, in accordance with our former views, that the creation of such a system requires great funds and lots of effort which cannot be substituted with enthusiasm alone. Unfortunately we still do not have the financial means to put this project into practice. In the spirit of a step-by-step march, we started the data entry with the Roman Collection using DataEase, based on data structure experiences obtained using MIDAS. All data of former registration cards, with the exception of the fusy and spacious description were fed in the system. We have started the registration of images belonging to the registration cards, though the storing space and speed problems encountered here will be solved only by more powerful equipment (SUN workstation and INGRES 4G RDMS, funded by an IIF grant to be installed in 1993). Since the beginning of our computerisation program, problems of terminology in the two great data acquisition systems of our collections were considered. A previously constructed and continuously refined and developed terminological system was used for the Roman Collection, while for the Topographical Register the data entry was done on the basis of the paper card system without modification, using a subsequent data processing program. In 1992, the Archaeological Department of the HNM won a grant of the OTKA with a project entitled Geographical Information System of Archaeological Collections. Our aim with the project is the creation of a modern inform-

ation system which will be suitable, apart from tasks of documentation and registration of objects, for the discovery of relational patterns of the data and for a complete spatial analysis. The GIS software adopted (GreenLine) is in OS/2 operational system according to our present possibilities but it is possible to convert the application for UNIX that will be necessary in view of the coming hardware and software platform in the HNM. Apart from the database constructions, we attached special importance to the development of software supporting research. The first step was the factor and cluster analysis of metrical data (Tamás Bezeczky). The software made after this offered further possibilities for an objective solution of classification which is crucial to archaeologists. Two software can be referred to here - the serration program of Attila Suhajda and the SERPA (Seriation's Environment and Research Program for Archaeology) developed since 1992, an effective data processing and evaluating algorithm for the material of cemeteries. The most important task for the coming 1-2 years in the HNM will be, apart from continuous data entry, the installation of the new hardware (workstation) and the development of an INGRES application which will be able to integrate the results of our current projects.

In the followings I would like to give a short summary of events of the last decade regarding the adversities of the museum application of the computer technique in the Hungarian National Museum. I intend, first of all to inform about present activities and also about the developments proposed in the HNM. At the same time, I think our experiences may be used by others in their own fields.

The HNM was among the first to develop its own computer development project. Due to the lack of real computer equipment, such tasks were placed in the focus during the 'heroic age' that aimed the modernisation of traditional documentation and its preparation for computer analysis as the adaptation of the archaeological descriptive card suggested by the MDA and the start of elaboration of technical terminology.

These first steps, however, were not unanimously accepted by the professionals. The introduction of the new ("green") card where the data structure and logic of its filling represented a step toward the acquaintance with relational data structures, could be explained by the insufficient and inappropriate data system of the accepted "general archaeological descriptive cards". The elaboration of a technical term system, however, which would have necessitated the consensus and collaboration of the whole field through many years, could not be made accepted. This lack, the lack of a unified Hungarian archaeological term system, still raises many problems at the introduction of computer systems.

In 1986, the Archaeological Institute of the HAS, the Department of Archaeology of the ELTE and the HNM won a joint OTKA competition to develop an archaeological computer data register system. This financial background enabled the acquisition of the first and minimal hardware and software devices and the start of research. Here, it should be mentioned that about 65-70 % of the hardware and software equipment in the HNM were obtained with the help of aimed promotions and offerings of foundations.

The first research-oriented software in the HNM were made within the frames of the OTKA competition. Such were a graphic program enabling two or three dimensional depiction, a mathematical-statistical program (M' ARCH), which, using the data files of the previous software as an input aimed the resolution of grouping problems, and also a data base program for archaeology all on a Clipper basis and with regard to the contemporary level. It turned out already during the development phase that the software and hardware we had were not sufficient to build a basis for the museum informatic system we had envisaged, still the joint work invested in this system planning did not prove futile.

By 1989, a mass demand emerged in our field for the spreading of a database software in the museums. By this time, however, software with new concepts had already appeared with a wider scope than the home developed data base programs, so the HNM also suggested the general introduction of the DataEase to the Ministery of Education in 1990.

In this period, conferences, meetings and exhibitions were organised in the museums where we tried to circumscribe the most important and basic questions of the computer development in our field and where several debates preceded and followed the acquire of the DataEase. I still hold that at that time we could not do more for the creation of a unified museum system than the introduction of a relational database program at an accessible price. We could leave behind the do-it-yourself phase, still it was not yet possible to put a fulltext system or a document archivator on everybody's desk. This decision, however, did not impede anybody to develop an own system, since DataEase was only a suggestion and accepted with a consensus: only the minimal data content can be compulsory.

The quick development of computer technology, the experiences derived mainly from our own mistakes and the more and more perfect computer system developed on the already existing bases brought the ultimate aim, the creation of the archaeological database in full perspective. Beside the formation of a relational DataEase database, with the help of an adapted document archivation system, we could solve the otherwise problematic presentation of figural information. Under the multitask DESQVIEW, the text and figural data together with a video data base supplementing them could be handled together in one system. Since 1990/91, owing to the IIF program house, we could join the national and international computer systems and with the help of the sum gained from the database building competition of the IIF, the "Archaeological Database of Protected AREAS" was founded which can be reached on-line from the host computer of the MTA SZTAKI.

In 1991, due to the IESC, N.Statland, an acknowledged system organiser from the United States elaborated a four-year-project in a month for the HNM which contains the setting up of the whole informatic system of the museum. The project deals in minor details with the tasks to be fulfilled, the possible solutions and the necessary human and financial sources. The project revealed in every detail (also in budget) the several time repeated and never really accepted fact that the creation of a successfully working system needs big afforts and much money which cannot be substituted by enthusiasm. Just a few data to illustrate the grade: the project counts with 80 000 working hours of a museologist (i.e. 4 years of work of about 10 museologists) and about 20 000 hours of data typing during the data input and data conversion period. The calculated total budget of the project is 20 to 24 million Forint depending on the chosen solutions.

Regrettably, we do not have the financial background to start the whole project. We must carry on with the tactics of small steps. Accordingly, after the introduction of the DataEase, as a first experiment, the elaboration of a smaller unit, the Roman Collection of the HNM was started in a data structure based on experiences gained from the "green cards" and the MIDAS development. We tried to shun all extremes.

Nearly all the data of the descriptive cards were put into the system except for the so-called description fields (Regrettably, the static place occupation of the DataEase does not allow to handle the presented problems of capacity in a suitable manner).

It is in important aspect that the picture archivation system under the Windows, which is a developed version of the DISCORP, we have the possibility to register the pictures attached to the cards and also to reach the above mentioned video data base if the object would need such a picture documentation. Although the database-picture base link is not yet thoroughly elaborated in this structure, and we do not have enough capacity to deposit all the picture files, we would soon like to start with the input of the pictures that belong to the already registered approximately 30.000 items. We hope that the (SUN) hardware and the (INGRES) software won from the IIF Project competition will be able to solve this problem after the necessary developments.

Another significant difficulty in the course of data input was caused by the problems of terminology existing since the beginning of computer developments. To put it simple and polarised, two extreme basic aspects have formed in our field. One holds that a terminology should be developed in advance based on a scientific agreement (an opinion the HNM and me myself shared for a long time). Regrettably, we had to learn that this is a practically hopeless endeavour. According to the other aspect, no preliminary terminology is necessary, it will come as a result of data input.

In our two active data input systems (the Roman Collection and Topography System to be discussed later), two different methods were chosen to meet the recquirements.

In the case of the Roman Collection, a small thesaurus of about 130 denotionswas set up. The demotions were preliminary chosen from the inventory book and this was the first block of the data input. The objects which could not be grouped, were put under the heading "others". Later, at regular intervals, the items of "others" were listed and new types were defined from them to enrich the thesaurus. The data were accordingly updated. It means that the task was solved with a method similar to iteration. To date, the thesaurus contains 237 types of objects.

This solution did not seem appropriate for the other great data input work, the Topographic System which started with the Prehistoric Collection counting more than 200.000 individual objects. No preliminary terminology could be set up so the demotions on the cards were transferred into the system without any change. An good example to characteristic of the ratios is the fact, that after the input of 25.000 objects, there were more than 2000 demotions (actually "types") (sherd, sherd fragment, pottery fragment...). The solution here seems to be that after the input of all the data, a "dictionary" will be developed with a working program (sherd fragment, pottery fragment, vessel fragment...=sherd fragment) to modify the data, which will lead to a terminology. Whether this or that of the two methods is profitable in either cases depends on the size and the character of the given collection to be registered.

In 1992, the Archaeological Department of the HNM won an OTKA grant of four-year-run with an essay called "Archaeological collections informatic and spatial informatic system". Regarding the fact that barely 6-7 years ago even a PC was a rarity in museums and that, in our days, our science is at the final phase of the (childhood's) period of "database above all", one cannot be astonished that relatively few people know what spatial informatics really is and even these few people understand it in various ways. With regard to the papers submitted in this conference, I would only like to give an overall sketch of what aims the HNM endeavours to reach with its own Topographic System.

One of the bases of all GIS systems is a database dependent on the field of application Here and now, we tried to combine the pleasant with the useful and decided on the archaeological collection in the HNM as a relatively large "sample" data base, which sooner or later should, anyhow, be computerised and where the lack of a reliable topographic index is experienced every day. Why this data assemblage serves only as a "sample" is explained by the analysis function, one of the most important elements of the system we envisaged. Namely, the advantage of the GIS systems is, beside the evident documentation and database possibilities, an analysing module where the data base specific (here: archaeological) data and the topographic data can be combined and a different dimension can be demonstrated than at sample database queries.

Naturally enough, an ideal database should aim the "perfection" regarding a given period. As the collection of the museum is "random" from this point of view, it does not meet this demand. We hope, however, that such ideal systems can be created in the future with the addition of digitised databases of other collections.

Another basic element of the Topographic System is a IS software which, together with spatial informatic equipment, allows the presentation of various data, connections and relations, the realisation of complex spatial informatic analyses and which is also suitable to be used as the basis of a partitioned informatic system where text, maps and picture data can alike be handled.

From the rich offer already present in Hungary, we chose a Hungarian software. There were several reasons. On the one hand, the "intelligence" and references of the system were convincing. It should also be regarded that the development of the software was made according to the demands of the users by a company with which we had already had good contacts. Constant consultations gave the opportunity to correct the system and shape it to our demands in knowledge of all the possibilities. We were not compelled to receive something developed on the basis of an order where it could only be revealed later if it was good for us, how far ahead we can think and hoe deep our problems were understood by system designers and, furthermore, to what extent Murphy's quoted law realises.

We hope that this GIS software will be suitable to fulfill registration and first of all research tasks. At present, the system rubs under OS2 operational system but there is a possibility to shift to e.g. UNIX what we would soon like to do.

The above demands reveal the necessity of the general collaboration of museums and collections and the collection of data in order to create an overall spatial informatic system. The sheer fact that the creation of such a spatial informatic system, its hardware and software conditions cost a lot of money underline this necessity. Three or four years ago we said that the development of parallel databases was a waste and now it would be difficult to find a more emphatic and suitable word for parallel spatial informatic developments. It is nearly certain that, in this regard, the logical aim is a single system with an overall database basis meeting all the demands which can be distributed in a way that everybody could reach it. The entrance into the national network sponsored by the IIFP and, consequently, the entrance into a central system, I think, may appear as a reality in the near future for at least the county museums.

In a few words I would like to speak about the tasks we have to solve. First of all, we would like to devote great energies to the digitalisation of the data, both text and picture, since we have learned that it is in vain or no use to wait for a "perfect" system that would meet all the demands. The data once digitised (unless input is made in a perfectly closed system) can be used in the next, better and more perfect system as well. As we ourselves lave lost much time, the only thing we can advise is not to wait any longer. If there is a minimal possibility, start to fill up the database and hope for the future. We do the same when we compare the grade of the task to the INGRES system. Hopefully, we shall have enough money and patience to develop the system, which, knowing the present possibilities of the INGRES, may be a real basis for a data registration and research informatic system for museums.

In the following part of my paper, I would like to tell about a new direction of development, in a way different from the previous, which, hopefully, will get a greater role in the research plans of our institution. The problem of the GIS system actually led us from the problem circle of the inventory and databases to the development of research-aid software. It may sound somewhat mystic and there will be people who do not agree with me in the denotation of this type. This circle is difficult to exactly define since such a program may be written in DataEase DQL, in Basic or in Turbo C++ but perhaps the group it denotes can be understood by everybody.

I fear, our field of science lags far behind the international level. We have neither enough quantity of digitised data content nor sufficient capacity of specialists to solve these tasks.

Such work is carried out in the HNM within the frames of individual research programs. Understandably, no similar aims were described in the great projects of the museum. The first step in this field was the factor and cluster analysis research of the metric data of amphorae carried out by Tamás Bezeczky. Later, the software developed by us (ARCHIDAD, M'ARCH) offered further possibilities for an objective solution of the grouping so important in archaeology. Two more software developed in the HNM can be added, the serration system SERPA (Seriation's Environment and Research Program for Archaeology) by Attila Suhajda which is effective for data elaboration and analytical iteration algorithm, for the joining of programs used at cemetery analyses and which originally do not support each other. From this regard, it is also an experiment to function as a program system.

There is yet another fact is in strong connection with this problem circle. Namely, it must be emphasised that the users should be careful at the use of these programs developed specifically for research. We may use, naturally, the systems with series of complex mathematical methods and they will give results in accordance with the structure of the machine. The authenticity of these results, however is 50 % according to the theory of probability that is they may be true or false. (Murphy says: "From a sufficient amount of data anything can be proved with the help of mathematical-statistical methods.")

A mathematician who deals with sociological analyses wrote recently:

"(Mathematical-statistical software) ... can easily be handled and learned even without any deeper knowledge of statistics. Their greatest disadvantage or source of error lies in this very fact since complex multivariate analyses can be made with the system without any scientific control even in total lack of basic statistic requirements."

Turning back to the earlier mentioned cemetery analyses, a similar analysis aiming real exact results sows further than the distribution of a few types according to objects (with the help of mathematical arrangement algorithm) and the order of settlement features (the basis of serration). Such problems may arise as type formation, within it the choice of characteristics (data) and the analysis of their impact on classification methods, the archaeological application of classification methods and metrics, or a refinement of results and data with iteration methods and the definition of the concept of seriational and archaeological types. All these questions must be examined from both sides, otherwise (either archaeology or mathematics is neglected) misinterpretation has a growing probability.

The programs often allow the application of such mathematical methods that were made for specialists. An example is the cluster analysis included in many programs, also mentioned souring this conference. As more and more researchers use this method in archaeology I would like to call attention to a few aspects and through an example ask the colleagues to be careful with analyses of this type.

I would like to cite the opinions of a few specialists of this topic.

First I will quote Ottó Gulyás, one of the greatest specialists of the topic in Hungary:

"The theory of cluster analysis is still undeveloped, there are many theoretical problems not yet resolved. The number of the practical application's and algorithmic trials with computer, however, is very great."

Another Hungarian specialists writes similarly:

"There are two things that impede researchers to use cluster analysis. One is the conviction that deeper and more detailed knowledge will rather help to get closer to the resolution of a problem than some conjured manipulation on earlier data. The other factor is that the cluster methods are not dressed in the brilliant outfit of the theory of probability, they are easy to calculate but the result is fairly instabile against mistakes."

A technical book on the topic writes the same:

"It is difficult to decide about a cluster analysis if it is congruent with the aim, if it realises the clusters that can be used, which is not primarily a mathematical or computer technical problem. Accordingly, the results of a cluster analysis should always be regarded and accepted with critical approach."

Finally I would like to quote a classical statement:

"Anybody who is prepared in matrix algebra, knows some classical statistics, geometric and something of the theory of sets perhaps also theory of information and of the graphs, something of computer technique and has the access to a good computer and who enjoys mathematics, he probably can develop a new cluster method that is much more useful, modern and so more delusive than the mere grouping of animals and plant or the elaboration of their history of development."

With all these I did not want to divert anybody from the application of either the cluster analysis or any other mathematical-statistical methods but I would like to call attention to the careful evaluation of the results, the complexity of the problem circle.

The Information Infrastructure Program (IIF) for Research, Development and Higher Education (1986-1993)

Ferenc Springer
IIF Co-ordination Bureau

IIF is a program supported by the National Committee for Technological Development (OMFB), the Hungarian Academy of Sciences (MTA), the Hungarian National Science Foundation and the Ministry for Public Education, for establishing computer network based information services for Hungarian universities, higher education, research & development institutions.

The first phase of the IIF Program started in 1986. The original plan included to set up a computer network as well as provide information and communication services. The majority of our resources were spent on the acquisition of intelligent terminals (PC-s) and LAN-s. the design and development of the packet switching communication system. Our efforts at that time were also burdened with COCOM limitations.

The first phase of the IIF Program has been successfully implemented. All the important universities, academic institutions and some large companies joined the IIF community.

By now, a network based information system is at the disposal of several thousands of users. The system is based on international and de facto standards (X.25, XXX, UUCP), ensuring the interaction with international networks. The IIF Program provides important services (national e-mail service, bulletin board, file transmission) and full screen access to a wide range of data bases.

Now the program is in its second phase (1991–1994). The basic development concepts focus on the progress of information technology.

Most important elements of the concepts include the development of the data network, the installation of regional and disciplinary centers, installation of wide area network. We strive at enhancing the possibilities of the electronic mailing system and the database service. Also, IIF supports educational and training programs for users and professionals as well.

Special efforts are taken to forward the use of unified standards in electronic mailing, directory services, interactive access, file transfer services. The services characterising the co-operative systems should be established and widely used.

Theses for the informatical development of the museums

Gyula Engloner–Attila Suhajda–Katalin T. Biró

The 1991. December Management Meeting of the Ministry of Education accepted a decree on the development of the infrastructure of higher education and public collections.

The main aims of the project were:

– the use of computers should became a routine means for students in higher education

– the museum professional staff should adopt modern means of information techniques in their work, and use these means for opening up and exploiting the information wealth deposited in the museums which is a part of national property and should offer this information for education and research

– due to the services of Hungarian information databases an important export could be formed as a counter-value of information import we badly need.

These purposes as well as other goals not directly referred to here as well as professional arguments indicated us to make the following proposal for the participants of the meeting, to discuss, accept and pass to competent authorities:

1. The hundreds of million objects, pieces of art etc., represent important national wealth, the proper use of which is a national interest.
   The efficiency of utilisation is determined by the means available for it, technical and technological endowments which render the information concerning museum objects available for Hungarian and foreign citizens (research workers, students, tourists etc.)
   The most efficient means for this purpose today is represented by the complex information infrastructure including computers, telecommunication and video-technical media.
2. Public collections - including museums - are the basic source of higher education. In these institutions - universities, high schools etc. - the past two years have brought about essential development in information technology concerning the supply of means. According to a survey performed in 1991/92, the number of IBM compatible machines increased three times. The performance of the computers rose accordingly and even more. In two-third of these institutions local network system facilitates interior communication. About half of the PC-s are organised into LANs. More than half of the institutions are capable of exterior communication by more than 3000 terminals. In several of them there is an integrated information system installed.
   The above data reflect state of affairs in 1992 - since that date, further dynamically development could be observed.
   As opposed to the dynamically development of the institutions of higher education, museums are still legging behind desirable standards.
   According to the statistical survey of December 1992, for one single PC 2.5 museum research worker, 11.43 museum employee, 48048 museum object and 23700 visitors are allotted. More efficient equipment than PC-s were not reported from the field at all. The number of museums connected to the national network is 7 (0.9% of the museums, 0.2% of the computers), while local network was reported from 7 museums (possibly 28 PC-s affected, 0.9 of the museums and 6.6 % of the PC-s).
   Students, teachers and research workers at the universities can only access the wealth of information stored in the museums with the speed, accuracy and quality

by our age if this information is stored in computer databases which can be searched through network systems.

3. Higher education and academic as well as profit oriented research requires a lot of information which has to be imported from abroad. A part or all of the information import could be counter-valued by export of information. One of the decisive conditions of the exportability of the information wealth is the existence of high quality databases, information systems. This means proper conditions of hardware, software, netware, organisation of suitable systems and applications, data entry, storage and maintenance and the personal and technical conditions of these informational services.
4. Most of the graduating new students can only obtain their qualification if they have a basic user's knowledge on computers - word processing, data acquisition, electronically mail etc. New generations of research workers will come to work armed with practical knowledge on information technology. It is desirable that they should use their knowledge and they would not be forced to leave the field lacking basic conditions of infrastructure.
5. A number of museums will be possibly affected by the coming World EXPO of 1996. Most of the visitors coming to Hungary for the occasion will possibly visit museums. Their choice, previous information will largely depend on how they can get quickly informed on their possibilities. The informatical development of the museum field would essentially further the formation of tourism and influence people's view on our culture and fame.
6. Most of the visitors of museums are children, students of elementary and secondary schools, who are known to have a special devotion towards computers and video technology. We are convinced that on meeting these media in interactive exhibitions would contribute to their acceptance of the museum world. This would mean an essential step towards the rise of prestige and the appreciation of the museums in the society.
7. *In view of the above facts, the participant of the Conference will further the following motion towards all parties interested:*
   - the informatical development of the museum field should be a high priority task for the museum management, in view of the possible advantages of the application of modern means of information technology and considering the grave consequences if these requirements are not met. Personal and financial consequences of this high priority status should be considered.
   - the inadequately financed museum field should receive funds necessary for this development which cannot be paid from the waning costs of maintenance, but as a minimum goal, costs of closing up other fields of science and education should be established.
   - higher education and research should consider the public collections, among them, museums, as an integrated part. In the hope of future advantage, the informatical development of the museums should receive equal priorities like institutions of higher education in funding, development and public attention.

Excavation documentation of Alsórajk-Kastélydomb in GIS system

Ferenc Redő
Archaeological Institute of the HAS

Archaeological objects of multi-layer sites are normally situated in superposition. The interaction or difference in their direction are important questions to be answered. It can serve as arguments for separating chronological periods or, within larger chronological units, it can render certain periods together. It can be a sign of centuriation or the main route system of the settlement and its surroundings. Directions can be explained by geographical, climatic reasons and changes in these factors.

Computer graphics enable us to register these changes. Forms can be projected over each other and gives a possibility to treat units separately which is in itself a great help in correctly interpreting the evidence at hand.

The excavation evidence later can be completed with further data, i.e., geographical observations and soil analyses. This way we can give more adequate solution to some problems and raise new hypotheses which take us nearer to the solution.

The case study serving as a basis of my lecture will be the detailed archaeological survey (micro-regional project) of the Archaeological Institute of the HAS performed in the Hahót basin.

One of the important sites of the work carried out here is Alsórajk-Kastélydomb, where a multi-layered Roman villa is overlain by a medieval church and monastery as well as the attached cemetery.

The geometrical pattern of the fragmented Roman villa could be largely reconstructed by graphical methods.

A new interdisciplinary workshop, the 'Archaeological High-Tech Centre'

Ferenc Gyulai
Archaeological Institute of the HAS

The World Bank and the OTKA launched a project in 1991 to furnish centers of scientific research with high technology equipment for the benefit of the scientific community under the name "Műszerközpont" (= High-Tech Centers). A team of scientist working in interdisciplinary research on archaeological objects participated the project and founded the 'Archaeological High-Tech Centre'. The proposal was accepted and, as a result of it, a complex image analysis system - valuable microscopes, computers and specific software can be obtained.

Probably by autumn the system will start working: in our view, the continuous run of the Centre can be expected by 1994.

The measurements and analyses planned to be performed by the help of this system include, in the first place, historical studies in the wide sense (archaeology, mainly its interdisciplinary sub-branches: archaeometry, archaeobotanical, archaeozoological research) but also we are planning to work for other branches of science to support the maintenance of the Centre, i.e., biology, agrarian sciences (study of plought seeds, soil studies, palinology), as well as technical sciences (morphology, shape recognition), geosciences (mineralogy, palaeontology etc..), as well as industrial applications.

The primary goal of the Centre would be to support interdisciplinary applications but also basic research education are planned to be in our focus. We are ready to undertake some technological services as well (e.g., quality testing) and support public education.

The analyses will facilitate the mass analysis and documentation of micro-traces obtained during excavation that would otherwise be lost for us.

Naturally, the actual studies will always be directed by the task.

Some aspects of analyses planned to include, according to our preliminary plans, the following fields:

a) **Archaeometrical studies**

The analysis of organic materials
– Archaeobotanical samples: determination of species and subspecies
study of micro traces and food remains
quantitative palinology and xylotomy (study of arboreal tissues)
anthracotomy (study of charcoal), dendrochronology
– Archaeozoology: determination of species and subspecies
metrical study of the microfauna, biochronological evaluation of growth layers, pathological studies
studies on the use and damage of the bones
Study of inorganic materials
Natural materials: provenience, micro traces, traces of use, textural features, quantitative analyses of petrographical thin sections
FTD analyses and hydration chronology (obsidian samples)
analysis of grain size

– Artificial materials

provenience and evidences of use and production

b) **Analysis of field video documentation, map information materials**

c) **Other visual information which can be analysed by the system**

Most of the studies outlined above will be possibly needed by the Hungarian museums and research institutions but we shall have the possibility to accept tasks from other customers as well for the support of the Centre. In our plans we would like to secure related technical/scientific studies and education purposes as main profiles.

The Archaeological High-Tech Centre will be operating under the gestorship of the Archaeological Institute of the Hungarian Academy of Sciences (H-1250 Budapest I. Uri utca 49. Telephone: 1-759-011/539, Fax: 1-564-567) as a non-profit, economically independent and self-sustaining unit.

Scanning Electron Microscope as Multidimensional Input Source of Image Analysis

Attila L. Tóth
Res. Inst.f. Technical Physics of Hungarian Academy of Sciences

After the appearance of computer controlled instruments it became clear, that the scanning electron microscopy (SEM) is more than simple extension of optical microscopy into the high magnification range. Its basic properties, as the scanning principle, simultaneous multisignal detection, straightforward digital control and data acquisition, pixel by pixel pre-processing of signals all provide new possibilities in quantitative image analysis of micro regions.

Scanning principle

In its basic working mode the energetic electron beam of manometer diameter is swept in a TV-like raster over a micro region of the sample. The magnified image is generated by synchronous visualisation of the generated signal intensities on a cathode ray screen. The most common secondary electron signal gives images showing the sample morphology with a magnification of 10x-100.000x.

Digital control and data acquisition

Due to the scanning principle the SEM is ideal input device of the image analysis. There is no need of digitalisation by camera or scanner. The scanning electron beam can be controlled by computer, and the generated signal can be digitised directly into the memory for processing, visualisation or storage. The size of the digital images is limited by the controller DAC, while the number of gray levels is determined by the measuring ADC resolution. Images of 4000x4000 pixel with 2000 gray level are easily attainable.

Multichannell detection

As the signals of the SEM carrying different information (secondary, back scattered, trans-mits electrons, cathodoluminescent, etc..) are generated simultaneously, a whole set of images can be collected during a single scan using a multiplexed ADC with the appropriate detectors.

Micro experiments point by point

Considering the SEM as an analytical measuring system the possibilities are still wider. According this approach local experiments of electron-solid interaction are conducted, modulating the excitation, the sampling, the sample environment and the detectors. From the generated response vector after demodulation complex analytical information can be obtained, which includes the different images as well as non spatial distributions of physical quantities, being functions of multiple excitation of requiring point/by/point quantitative interpretation (chemical, CL or microelectronics spectra, depth distributions, channelling patterns). Using computer controlled SEM the results of these complex local experiments can be mapped together with the different digital images carrying morphological and other information (similarly to the multidimensional input of multispectral images of Landsat type satellites). The full exploitation of these possibilities requires close co-operation of the archaeologists with the specialists of image analysis and SEM.

The Role of the Sun in the Ritual of the Copper Age Burials in the Carpathian Basin

Katalin Barlai–Ida Bognár-Kutzián***

* Konkoly Observatory, Budapest

** Érmelléki u. 1., 1126 Budapest

The orientation of the graves and skeletons in prehistoric cemeteries has been considered to be of extreme importance in archaeology. Quantitative studies can only be done in cemeteries where the archaeologist had measured the axes of the graves and of the skeletons unearthed or at least a precisely drawn map had been prepared in the site. From several hundred cemeteries containing thousands of graves only few can be found which are adequate in quality.

Concerning the burial rite there may be two presumptions.

1. A given preferred direction has been determined. The dead person was supposed to be laid in this direction (e.g. the geographic E-W), which was kept in grave digging.

2. The direction of the daily sunrise or sunset played a role in orienting the grave pits.

We paid more attention to the orientation of the grave pits. In our view it could have been determined deliberately. The final position of the skeleton, however, can be result of some accidental factors too (particularly in case of contracted skeletons), when laying the corpse into the grave pit.

Plotting the number of graves versus the angle deviation from the magnetic North direction the resulting histogram shows the angle distribution of the graves in a given cemetery. The "bottom" of the histogram of the Basatanya Copper Age cemetery (155 graves) fills in just the so called "solar arc", thus the angle interval between the sunrise (sunset) directions of summer and winter solstices at its 47,5° geographic latitude. This fact can support our second presumption, or can be mere coincidence. (The six other cemeteries: Bodrogkeresztúr, Jászladány, Pusztaistvánháza, Deszk, Kotacpart, Tibava used for comparative studies do not contradict to this presumption either.) Still the investigation of one single cemetery does not allow us to decide in favour of the first or second presumption. To settle this question another approach should be sought for.

To check the connection between inhumation and the solar arc, cemeteries at different geographic latitudes had been studied. The investigated cemeteries are roughly contemporary, and while belonging to the different cultures are still not incompatible. First the Eneolithic (Chalcolithic) cemetery Olenii Ostrov in Lake Onega at 62° northern latitude has been studied (81 graves). A solar arc of 116° belongs to this geographic latitude. The bottom of the histogram of the cemetery covers 120°. This fact can be taken as evidence for the role of the actual sunrise or sunset in the burial rite. Another example can be the Muntenian Cernica cemetery, belonging to the Cernica phase of the early Boian culture. The bottom of its histogram constructed from more than 300 graves fits well into the solar arc at 44.5° geographic latitude.

In the investigated cemeteries the graves fill the solar arc corresponding to the geographic latitude of the site as it can be clearly seen from the "bottoms" of the histograms. This fact suggests that the daily sunrise or sunset played decisive role in the Copper Age mortuary practice.

Measurement of bone mineral content in archaeozoology

László Bartosiewicz*, Wim Van Neer**, An Lentacker** & Bea De Cupere**
* Archaeological Institute, H. A. S. Budapest
** Royal Museum of Central Africa, Tervuren, Belgium.

Bone density has broad implications for taphonomic loss (Shipman 1981). It is, however, also related to the function of bone. While overall density may be estimated by simple weighing and submerging respectively (Nicholson 1992), more sophisticated methods are required to map the distribution of mineral content within individual bones. Computer aided estimations were carried out using a Hologic QDR-1000/W apparatus in order to establish the degree of ossification in the distal epiphyses of modern and excavated cattle metapodials. This method is based on the X-ray absorption of the bone transformed into g/cm¸ values corresponding to the dorsopalmar/plantar aspect (Lyman 1984). Differences in the longitudinal distribution of bone matrix provided information on both age and bone function. Computer simulations by Atchley et al. (1976) showed that the absolute values of correlation may be biased in parametric bi- and multivariate analyses when data are scaled in order to remove the effect of size on variation. Relative increase in mineral content was thus estimated instead of mean "densities" provided by the equipment.

This text presents research results of the Belgian program on Inter university Poles of Attraction initiated by the Belgian State, Prime Minister's Office, Science Policy Programming. Measurements were carried out at the Catholic University of Leuven.

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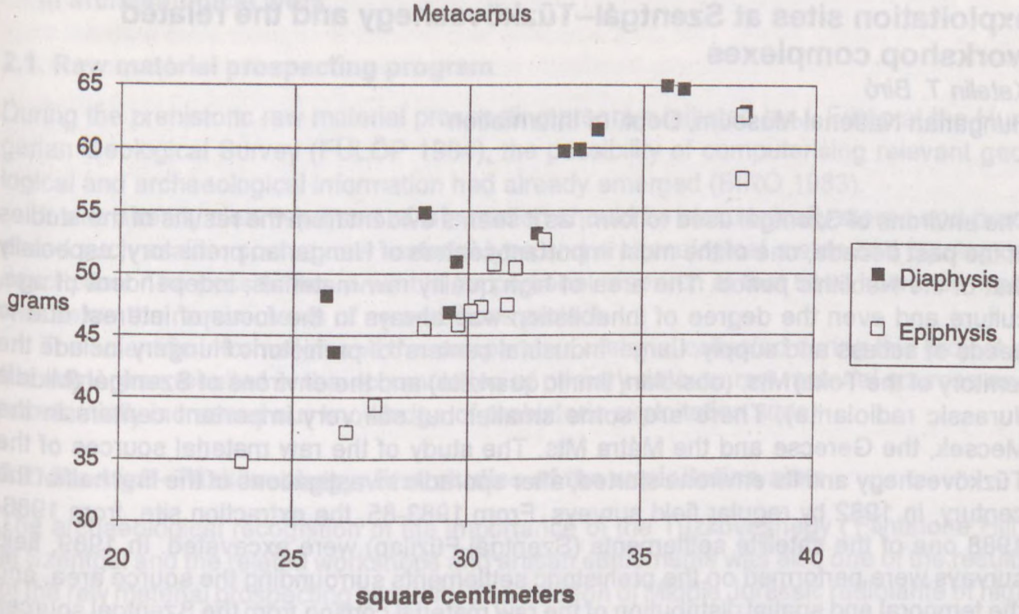
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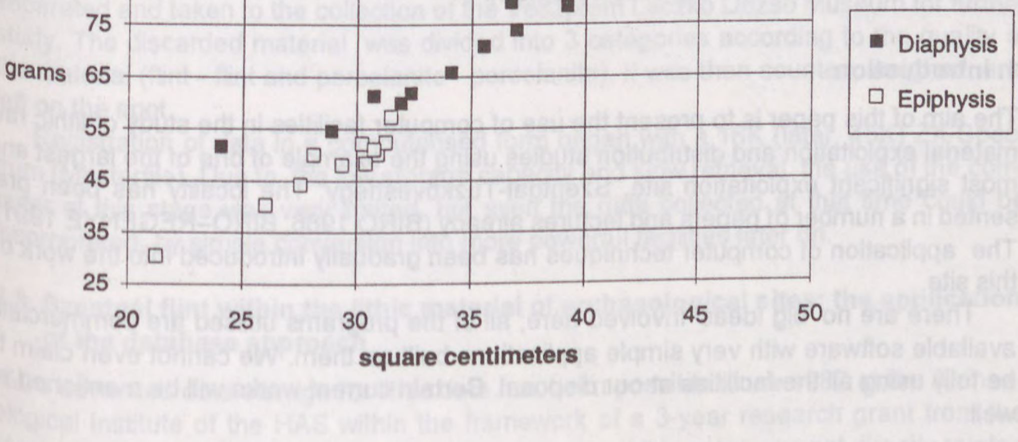
Metatarsus
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Diaphysis
Epiphysis

The application of computers in the study of the lithic raw material exploitation sites at Szentgál–Tűzköveshegy and the related workshop complexes

Katalin T. Biró
Hungarian National Museum, Dept. of Information

The environs of Szentgál used to form, as it seems evident from the results of the studies of the past decade, one of the most important centers of Hungarian prehistory, especially that of the Neolithic period. The area of high quality raw materials, independent of age, culture and even the degree of inhabitation was always in the focus of interest due to needs of access and supply. Large 'industrial centers' of prehistoric Hungary include the territory of the Tokaj Mts. (obsidian, limnic quartzite) and the environs of Szentgál (Middle Jurassic radiolarite), There are some smaller but still very important centers in the Mecsek, the Gerecse and the Mátra Mts. The study of the raw material sources of the Tűzköveshegy and its environs started, after sporadic investigations of the first half of the century, in 1982 by regular field surveys. From 1983-85, the extraction site, from 1986-1988 one of the satellite settlements (Szentgál-Füzilap) were excavated. In 1989, field surveys were performed on the prehistoric settlements surrounding the source area, and the temporal and spatial distribution of the raw material coming from the Szentgál sources was surveyed on Hungarian prehistoric sites. Computers were applied in the investigation process since fairly early dates. Most of the excavated lithic materials were registered in databases (using dBASE III+, FoxBase and DataEase 4.24 programs). Similarly, the distribution studies were based on the registration of available lithic industries of Hungary and beyond. Comparative raw material samples and analytical results, as a part of the Lithotheca collection, are registered in the Lithotheca database. For the presentation of regional and temporal distribution, more sophisticated techniques were used. Distribution data were elaborated by the help of spreadsheet and statistically based GIS programs (Quattro, TÉRKÉP, Surfer) on a map series. After that, the intra-site analysis of the excavation units was started using IDRISI, Roots and DeLux Paint. In our further plans we are aiming at a complete spatial analysis of the mine and its environment as well as a compilation of an exhibition demonstration program.

1. Introduction

The aim of this paper is to present the use of computer facilities in the study of lithic raw material exploitation and distribution studies using the example of one of the largest and most significant exploitation site, Szentgál-Tűzköveshegy. The locality has been presented in a number of papers and lectures already (BIRÓ 1986, BIRÓ–REGENYE 1991). The application of computer techniques has been gradually introduced into the work on this site.

There are no 'big ideas' involved here; all of the programs utilised are commercially available software with very simple applications built on them. We cannot even claim to be fully using all the facilities at our disposal. Certain current works will be mentioned as well.

2. Szentgál–Tűzköveshegy; a case study on the use of computers in archaeological work

2.1. Raw material prospecting program

During the prehistoric raw material prospecting program initiated by J. Fülöp at the Hungarian Geological Survey (FÜLÖP 1984), the possibility of computerising relevant geological and archaeological information had already emerged (BIRÓ 1983).

It was already clear what sort of information should be electronically stored and processed such as site, source, raw material type and archaeological metric and typological description. The possibilities available for personal research at that time, however, were well below the requirements of an ambitious project.

The scientific information and the comparative material collected during this project at the same time resulted in the accumulation of primary data on raw material sources and substantially increased our knowledge of prehistoric exploitation sites.

2.2. Szentgál–Tűzköveshegy; first studies of the exploitation area

The archaeological recognition of the importance of the Tűzköveshegy ('Flintstone Hill') at Szentgál and the related workshops and artisan settlements was also one of the results of the raw material prospecting program. The location of Middle Jurassic radiolarite of high quality and aesthetic colour variety at an easily accessible point (geogr. location with modern traffic system) was the basis for one of the most important workshop and exploitation sites in Hungary - and even, in Central Europe. The importance of the site was recognised by local field surveys and excavations as well as the study of prehistoric lithic assemblages in Hungary and beyond.

During the first few years, excavations were located in the central areas of raw material exploitation (1983-85; BIRÓ 1986). The surface of the hilltop and that of the surrounding areas is covered by a thick 'carpet' of anthropogenic radiolarite debris - disturbed, broken and definitely worked over a more or less congruent area of one square kilometer. The first excavation strategy was to collect all stones from a modest surface area (4x2) without prior selection, which resulted in the accumulation of nearly 1 metric ton of lithic material. Rough selection of the collected material was performed on spot: the worked pieces were separated and taken to the collection of the Veszprém Laczkó Dezső Museum for further study. The discarded material was divided into 3 categories according to the quality of the material (flint - flint and porcelanite - porcelanite). It was then counted, weighed, and left on the spot.

Registration of data in a computerised form began with a 16K (later, 48K) ZX-Spectrum (Masterfile). Due to the low storage capacity and slow retrieval the use of the computer at this stage was very limited, but even the data collected at that time could be incorporated, by simple conversion into more powerful facilities later on.

2.3. Szentgál flint within the lithic material of archaeological sites; the application of the database approach

More advanced data storage for lithic data has been possible since 1987 at the Archaeological Institute of the HAS within the framework of a 3-year research grant from the Hungarian Academy of Sciences. The main purpose of this grant was not directly related to the elaboration of the Szentgál workshop complex; however, the data structure established for the registration of the results of lithic analyses formed the basis of current studies as well (BIRÓ 1990). This data structure was formed to register lithic material from archaeological sites, in particular habitation sites. Subsequent research of the area concentrated mainly on the workshop settlements surrounding the exploitation area (excavations and fieldwork between 1986–1989, BIRÓ–REGENYE 1991). This was partly necessary due to the complete lack of datable finds in the exploitation area. The data acquisition concentrated on Veszprém county but extended over the whole territory of the Carpathian Basin in a unified system, which was organised later into a relational database (dBASE III+, FoxBase and DataEase versions). Registration from the finds of the exploitation area was carried out using the original categories in the same system.

Analytical data on rock samples from the Szentgál exploitation site and raw material coming from this source area was also registered in this database.

2.4. Distribution studies supported by spatial statistics

The uniform concept of the relational database supported the gradually refined presentation of raw material distribution studies. This was made possible, partly, by the accumulation of site information. The number of sites with lithic material analysed increased gradually (1984: 30, 1986: 179, 1991: 400 sites studied). On the other hand, the development of the spatial analysis of archaeological data and the use of GIS software helped the interpretation of raw the material distribution data. Following a series of two-dimensional point maps (BIRÓ 1988), the first isoscale map of raw material distribution from Hungary was based on the distribution data of the Szentgál radiolarite (published in the paper written together with J. Regenye (BIRÓ–REGENYE 1991)). This isoscale map (and the series of maps to follow) was produced using a base map of Hungary with the coordinates of the localities in a grid of 300*200 designed for a CGA monitor and the statistical package Surfer 3D.

Apart from the isoscale distribution map, simple quantitative presentation of the lithic material (by type groups, raw material groups, size and volume) was made using simple spreadsheet programs (Quattro or QuattroPro).

The first isoscale map was followed by a diachronic, chronologically filtered study of raw material distribution where Szentgál radiolarite formed one of the main categories (BIRÓ 1991 diss.). In fact, Transdanubian radiolarite including the Szentgál variety proved to be the most important category within lithic raw materials according to the number of pieces (BIRÓ 1993 CAA).

2.5. Using GIS for intra-site analysis

The possibilities of GIS were also utilised in a very simple form in the interpretation of site evidence. Settlement features and excavation units were digitalised and artifact density data were presented by unit using the software IDRISI (+Roots, DeLux Paint) (BIRÓ–FEJES 1994). In more recent studies of the exploitation area (1993–94), stratigraphic information and archaeological features were collected with a view to 3D computerised presentation. The new excavations resulted in the discovery of mining features (trenches, pits) in the central area of radiolarite distribution. The confines of the mining area was studied through a series of shallow test pits. Both lines of study were documented using computer graphics. The DEM of the area as well as the 3D model of the mining features were prepared and we hope that they will become available in the form of an interactive museum presentation. The completion of this presentation is expected by 1995.

3. Summary

The study of the Szentgál–Tűzköveshegy exploitation area and workshop complex is a task for traditional archaeology. The application of computer methods was gradually introduced into on different levels. In this way, the results of routine archaeological and archaeometrical information can be presented in a more efficient way for the specialists and non-specialist museum visitors alike.

A possible model of database organisation for computerised archaeological excavations

László Domboróczki
3300 Eger, Munkácsy u. 3., tel .: 36-324-490

It happens frequently that in an archaeological site there are so many finds, so that the archaeologist cannot evaluate them properly. For example, when we have got more than 50,000 potsherds. The systematisation and the grouping of this material nowadays is inconceivable without adopting computer technology. Problems can emerge, however, when the aimed wide-ranging analysis demands too many data, i.e., too much of storage capacity per potsherd. With traditional database technique, even if we pay very much for storage capacity, we get ineffective, slow-working computer programs. By using well-organised databases we can minimise the loss in storage capacity and can have an effective, relatively fast working computer program. My report deals with a kind of possible organising method and its benefits. In case of further interest, illustrative computer presentation is available.

Until computers had gained ground in archaeological research, archaeologists may not think of analysing totally the excavated material, which sometimes measured close to 100.000 potsherds fit for evaluation. Probably was made a volume, dealing only with the most representing fragments and the remaining others were just casually surveyed. Nowadays even the traditional personal computers make it possible for archaeologists to analyse exhaustively their large amount of potsherds.

Exhaustive analysis means, that through every stratigraphic phenomenon - i.e. through layers, through objects - leadertypes could be shown, the most frequent as well as the exclusive find associations could be detected and it means also, that every statistic has to be available, which may contribute to the recognition of the characteristic forms and adornments occurring at the separate places of the excavated area.

The availability of the relevant statistics requires, that all the respects emerged during the course of the analysis can be related to one another and the common occurrences can be examined i.e.. every relation could be detected. This may be very important in case of large settlements, to where even funerals are joined to and where functional dissociation can be traced. These dissociation occasionally can be reflected by the differences of the articles of consumption.

This kind of analysis in case of proper amount of material can be accomplished only by the help of computers because of their large memory and quick associating ability.

The preliminary condition of the computerised work is the existence of some find- or ceramic-describing system, by which the material of an era can be classified. Nowadays exists a describing system, worked out by Dr. Raczky Pál for the hungarian neolithic and copper age ceramics. He was, who got under way the computerised methods at the Univ. ELTE Dept. of Archaeology.

His system can be devided into two parts. The first is describing the stratigraphic relationships, the other is dealing with the ceramics.

The stratigraphic part is registering the structure found at the excavation site. It consists of the categories of squares, layers, objects and stratigraphic units. The stratigraphic units are the smallest parts of the excavation, which can be separated from one another.

They have to be altered when the squares, the layers and the objects are changing. This method have already gained ground in Hungary by british and french samples. By the help of this system the finds can be assigned to the stratigraphy. The perfect spatial exactness is not involved in the system, only the definition of the surface squares and the giving of the absolute and relative depths is possible.

The ceramic describing system can be further devided into three major parts. The classification of the forms, the types of shreds and the adornments.

1. Here can be given the form of the potsherd. It can be defined only, if the potsherd makes it possible to infer to the whole shape of it.
2. The potsherds can be devided into classes, depending on which part of the pot they are. The shreds can be defined as rim, side, bottom, handle. They can be further refined. For example the bottoms can be distinguished as single, hollowed or tubular, the handles as horizontal or vertical situated etc. Potsherds can be devided into two or more classes simultaneously. For example in case of a whole profile the describing may be tubular bottom, side, horizontal handle, rim. Of course, further refining are possible.
3. The adornments can be classified as spiral, concentric, angular and figural carvings, aligned and space filler butting, black, red, yellow and white paintings, geometric, figural and irregular painted motifs, black, red, yellow, white and bitumen incrustations and open-worked, plastic and other decorations. It is also available here to choose more than one of the classifications mentioned above, for example black and red paintings and spiral carving.

Moreover, other attributes can be defined, for example surface-working, quality, size measurements etc. Other types of finds are also involved in the system, but I will not enter into their details.

Some words about the programming.

Each shred needs about 80 byte storage capacity by using traditional organising methods for creating our databases. It must be multiplied by 100.000 pieces and we get 8 Mbyte as primary storage requirement. If we want to follow with attention every relation amongst our data and if the fastness of the accesses is also important, we have to use as much index files as possible. Programming languages as dbase and clipper, in case of storing 100.000 records, need circa 3 Mbyte storage capacity per index file.

As we can see, the faster our programme is, the more storage capacity it needs.

By applying traditional organising methods, almost every field of the database demands an index file to provide the fastness of the programme. It would require further 40-50 Mbyte over the primary storage requirement.

With the optimal distribution of the the datafields to different databases and with the help of dynamic storage methods - data just there have to be stored where they have real value - we menaged to maintain the fastness of the programme and at the same time minimise the storage demands. In case of larger material, this type of savings are of great importance.

That every relationship can be shown by the programme between the stratigraphy and the typological characteristics, means approximately 10.000.000.000 different groupings or statistics. This is enormous, but many of them meaningless and have not importance at all. It depends on the archaeologists which are useful for them and which are not.

It is also important, that the statistic lists are made by the programme printed fit for publication and for the archaeologists simply have to collect them for the analysation process.

This programme was made in 1992 for the Univ. ELTE Dept. of Archaeology to help to analyse the material of Öcsöd, excavated by Dr. Raczky. This programme is supplied with working-help, has versions in dbase and clipper languages and available for those, who show interest. For neolithic and copper age material in Hungary it is fit automatically and to the material of later times it can be easily adjusted.

The plus, with which is could be developed, are the video technique at the form table and the creation of a motif database for the better classification of the ornaments.

But if we give definition to the stratigraphic units with real 3 D co-ordinates, the artificial squares would be unnecessary and the spatial graphic appearance could be realised with its many advantages.

The development of such programme have already begun in l992 and hopefully it will be ready in the near future. That will be a programme-package, with which the excavations can be modelled 3 dimensionally from every point of view, and which will be supplied with find-handler programmes. Every layer and object will be shown and finds and statistics can be assigned to them. Archaeologists will be able to make section, surface and generated drawings by the programme and to compare them to other drawings. In this way, making experiments, the historical reconstruction can be achieved. The most desired target on developing our system is to minimise the needed measurements to the creation of 3 D figures and to make the programme runable on traditional PC-s with minimal build-up.

Exists nowadays such kind of archaeological programme as well, which can help surveying excavation materials before wide-ranging analysis. It can also make several statistics on the bases of the stratigraphic and tipological characteristics, but it relies on registering data in larger groups and describing them not so meticulously. The registering process takes only few days and the stored information can be quickly looked over.

By applying computerised methods, the archaeologists can possess useful information which have not been available before. Once, the changing of the publications will infer the the changing of the databases, and the more spectacular methods hopefully will attract more public interests for the archaeology.

Computer registration of excavation evidence at Szombathely – Fő tér

Ottó Sosztarits–Zsolt Vízvári
Savaria Museum, Szombathely

Our lecture deals with a possible practical application of computers by the example of a topographical data acquisition system for the registration of archaeological data. We would like to present the method, means and practice as well as our concrete experiences during the work.

Computer registration of the excavation data at Szombathely – Fő tér (Main Square) and the data collection of the archaeological topographical database started collaterally according to the system published in the periodical Múzeumi Hírlevél (The archaeological topography of Vas County, Múzeumi Hírlevél (Museum Newsletter) XII., 1992. 11. 310-315.) Data are registered in a relational database (DataEase). The application was written according to the specific needs of the excavation process and is in progress ever since. Consequently, the data are grouped in three main units:

1. Archaeological features (in our terminology, excavation unit (kutatási egység, KE)
2. unique (individually treated) finds
3. mass find material

As an administrative task apart from the above mentioned professional data, we are using the system for the registration of the personal data of the staff and hands as well as producing paper-work for contracts.

The archaeologist makes a paper documented record on the topographical data of the archaeological feature under registration on a paper form and submits it to data registration. The obligatory data are continuously completed by the new evidence during the progress of the work and the description of features is specified. The data fed in the computer can be modified in the light of the new evidence. Due to the large surface and the complexity of the site (excavated area 4000 m^2, average thickness of the cultural layer 3 m) the data registration had to be made dynamically. The same reasons induced us to produce printed list-like evidence in course of the work which were of great help to us "standing by the pits".

Corrections on the lists were followed by updating the database accordingly.

Attached to the feature data we have the find register. The starting point in this case again is the paper documentation. The quantity of objects determined on the excavation far surpassed formed excavation practice. This is especially true for the data retrieval. The unspecified mass finds are registered by store-cases. This system enabled us to locate finds belonging to the same feature very quickly. Registration of data was performed on NoteBook machines using DataEase 4.24 RDBM. The structure used in our application can be used in other applications as well. We have found the program adequate for the task, operating with good speed and few mistakes.

We have brought with us a representative sample of our data written under the new, Windows version of the program already suitable for the registration of images as well. It seems that the new version makes data registration and listing even more comfortable.

StaTOR Information Sheet

István Torma
Tel.: 180-97-22; (06)-30-526-245

The Stator name of the software comes from the words: Status and DescripTOR.

It is written in C++ language of Borland, and needs only 270 kB in the memory - without data. The data are held mainly on the hard disc. For faster work you can use any cache program (e.g. pc-cache, smartdrv, ncache, etc.).

The StaTOR belongs to the CATH (Computer Aided THinking) and also to the hypertext category. The software is developed for IBM compatible computers using DOS operating system.

Features:

- StaTOR is a tool for organising the information, and for getting quick answers.
- According to the meaning of a text, the whole text can be linked to more information/descriptor. This is the most important feature of StaTOR, because an information (term) can be linked to a text, even if it is not literally mentioned.
- StaTOR is able to show the real context of a database/text/ with the structure containing subordinate and net relations.
- It is possible to create a database superstructured with conceptual system (technical terms, terminology, definitions, etc.) depending on the type of the sources. This conceptual system is the descriptor dictionary or thesaurus.

Limits:

The max. size of a database is about 32 000 records. (1 record = 1 text). 1 text cannot be longer than 32 000 char.

Availability:

The program can be bought and further information obtained from the author.

The data management system of the Museum of Aquincum

Katalin Szentirmai

The Registry System of the Aquincum Museum

In March of 1991, the Aquincum museum began computerised registration. The work was begun using an AT 286 computer and employing the DataEase program, paid for by the Ministry of Culture.

The original goal was to work out a registry system for the excavation drawing collection. This decision was motivated by the condition of the drawings which declined with every search through them. Thus, it became necessary to resolve the storage and registry problems at the same time in order to make the 5500 drawings from the last 100 years of excavation accessible as quickly as possible. Over the course of the past 100 years, streets have been renamed, plot numbers changed and streets and neighbourhoods torn down. These alterations meant that past searches for the documentation of a particular feature could take a long time.

Since, as far as we knew, no ready registry program specialising in drawing collections existed, we developed our own drawing registry system based on multiple reworking and experience.

The basis of the system is the aforementioned excavation drawings collection data card we developed. Apart from the inventory number, the card breaks down into two sections. One of the data groups is concerned with the characteristics of the site and the other with a detailed description of the drawing.

The definition of site includes the district, street, house number and plot number. It was necessary to prepare a general address description field as well since some of the older drawings containing location descriptions such as "next to the railroad station" or "facing the restaurant" could not always be placed within a modern topographic system. The first section also includes the name of the excavator and the year of excavation.

The second section of the data card includes the characteristics of the drawing.

The chief fields are:

a) The identification of archaeological phenomena such as walls, channels, ovens, and 56 other possible elements.

b) On-site profiles, ground plans, and possibly contextual drawings.

c) Topographic scale, level data, geodesic points.

Most often, our data cards make use of the list of the drawer number and arrangement/grouping within that drawer.

The essence of the registry system is that it should be possible to find each drawing on the basis of any of the above mentioned points. Naturally, it should also be possible to group or select from the pile using any of these variables. For example, one may initiate a search for all ovens and within this category, group them by site or excavator.

It took one worker about one year to enter the 5500 computerised excavation drawing data cards. At present, we are working on filling in missing data on some 1000 of these drawings. At present, the everyday scholarly work at the museum utilises this system in order to spare the drawings as the pause papers, in part because of age, are in a very fragile state. Thus, with reduced movement of the paper, redrawing becomes less necessary saving no small amount of money for the museum.

On the basis of the results from the registry of the drawing collection we have begun work on 40,000 items in the photograph collection. Here, we had to find the solution to a double problem. In addition to basic registry, great movement resulting from borrowing makes it necessary to keep continuous track of lending. The data card for the photographs is constructed similarly to that for the excavation drawing collection. They are also composed of two sections. Next to the photograph inventory number we are writing the inventory number of the object itself even if this necessitates looking it up some time after the fact. It includes the identification of the object and detailed description as,for example, the reading of stone inscriptions. The chief fields for excavation photographs include: the exact address, the topographic square and the description of the feature.

The way the system works is that the basic registry is connected to the loan card which automatically brings up the negative inventory number and the borrower's name so that it is only necessary to add the loan date. In this way, it is immediately apparent when looking for something whether the negative is available at that moment or not. It took one year to complete the work up of the photograph collection.

Once the excavation drawing and photograph collections had been entered into the computer it seemed most efficient to refashion the entire body of documentation. This yielded an interconnected system in which the drawing collection, photograph collection, inventoried and non-inventoried finds as well as publications and geodesic points are registered. The stores of our museum are located in various distant parts of the city. Work on manuscript preparation necessitated the imputing of inventorized finds - presently only by excavation unit. In this manner, many trips may be saved.

In the course of our work, it was important to develop a street name catalogue which incorporated in four time periods name changes over the past 100 years. With the help of this catalogue it is possible to look for and identify a particular feature which was excavated over several time periods, on the same plot but under different street names.

As continuous new demands came up, our registry system developed its uniform outline. From the beginning, we used street names as a base. Until this year, adjustments were needed because not all excavations could be connected to exact addresses. In order to be able to bring together the full documentation on a excavation we give our material excavation numbers. We put the letters 'AMR' which is a contraction from the name of our museum (Aquincum Museum and Ruin area). The 'AMR' number contains the excavation date, the geodesic 1:1000 square number, an identifier which provides more exact location information within the square as well as the excavation serial number in a given year. We define the identifier by dividing the 1:1000 scale square into 25 parts - which in themselves are equivelent to a 1:200 drawing. For example, this is the way an excavation number might look: AMR/93/039/022/005.

The AMR number accompanies all forms of documentation so that no matter under what name finds have been inventorized they may be retrieved later. We tied our entire material to this system and the street names. We have attempted, even after the fact, to identify each site. An example from the excavation drawing collection where the work has largely been carried out already: First we place the location of a planned or rescue excavation on the square of a map and on the basis of it look for the appropriate documentation. Under present circumstances, no matter when and under what address these drawings were inventorized it is possible to retrieve information using the AMR number. Some day we hope that when a material arrives in the restorators workshop it will come there under its own documentation number which follows it through inventorying as a growth-of-collection number. This is added to the inventory number of the object.

We have begun to try to inventories finds from recent excavations on the computer. Collegues are currently trying out three different experimental cards. The final card will be based on our pooled experiences. The registry of the inventory book detailed here contains 5500 excavation drawings, 40,000 photographs and 1200 old glass slides as well as the condensed material of the find inventory book with room for 2400 items and a 1300 item growth-of-collection notebook.

The basic registry system is closely related to exhibition activities at the museum. We have in-put objects from permanent and travelling exhibitions. This work is especially useful with foreign exhibits where we have less time available. The collegue bringing the exhibit gets a packaging, crate, and box list. As objects are sometimes reassigned new cases in different cities, the collegue whose task it is to dismantle the exhibit is also given a case list to aid in taking the exhibition apart and packing for the return to other countries or Hungary. Each list contains the object's name, inventory number and assigned catalogue number within a given country as they appear on the export permission. We supplement these data with the number of the photograph negative.

To conclude: Independently running inventory books are thus, inter-connected by street name, excavator name and feature. In each one may be found an AMR number. The documentation on a given object may appear in the fields of an individual card on the basis of the AMR. Archaeologists at our museum are currently working on the development of a documentation card for excavation finds.

Finally, in order to make the setting up and dismantling of exhibitions more efficient we have developed lists to aid in the location and packing of the exhibited objects.

It took one scientific researcher and two collection supervisors one and a half years to complete this registry system which contains almost 70,000 data.

Visual information

Zsuzsa Tószegi
National Széchényi Library, Bp.

Why do we weel flooded by databases 'spiced' with images and sound effects, with an immense speed and intensity? Who, and what can explain this sudden fashion of multimedia, which is forecasted to be the biggest business of the coming years and decades? Are we already fed up with alphanumerically data on the screen, whereas for centuries, LETTERs have been the main conveyors of human culture?

At the same time, this overwhelming amount of visual information forecasts a danger of inflation in itself.

Aren't we isolated enough by sitting alone in front of the TV screen and the monitor of computers?

Seems like taking on a special 'helmet' to exclude reality, to see nothing but 'cyberspace' and its artificial stimuli. Maybe, by this spectacular exodus from reality, we can only get more helpless in real world.

What has changed in human beings, to turn into virtual reality instead of real life? What needs must be met, with helmet on the head, in which not a peaceful museum walk is taken?

Is it only the level of technology, evolved to the height of our latent needs, or are we already the captives of our own technology? Who can give an answer? What is more, what shall be the fate of the guards and middlemen of traditional culture? Shall we stand in the queue and try to get our little slice of the pie from the Big Boom, or shall we accept the role of 'National Poorhouses', and slowly cease to exist?

Who knows the answer? Unfortunately, the author does not - she feels content to raise some crucial problems. The first among many: WHAT IS visual information?

From the information technology boom till social changes: archaeology, as an example

Z. Karvalics, László
University of Polytechnics

It is a cheap commonplace to say that information technology is basically transforming society. While bombastic adjectives are freely associated with these changes, like 'revolutionary', or 'elementary', these words are typically used for processes where these adjectives are not relevant at all. Reality is mixed with possibilities, the promised perspective is already enough for enthusiastic commentaries.

While on the surface we are concerned with the growth of capacities, brand new waves of electronic games, multimedia and networking, in the depth new structures and forms are born, which really lead to crucial transformation of social patterns. A crucial transformation, but not the growth of efficiency: a change of structure, not a mere renewal.

These changes are more intensively felt on the so-called information intensive fields like education, mass communication and different sections of science. By the study of a specific area it is apparent that the nature of challege is uniform, independent of the specific field.

This paper aims at analysing the personal background of archaeology, as a branch of science, its manpower structure, methodology and role.

The following statements are formulated:

– Information technology re-structured the 'human infrastructure' of the profession, creating brand-new tasks and spheres of activity. Part of these did not formerly belong to archaeology, while others became independent from former part-time activities.
– The new generation of technical equipment seems to promote the ability for the production of information. In fact, it is reorganising the paradigmatic frames of the profession by a new quality of accessibility and elaboration as well as the order of magnitude of the elements included in the investigations, raising local level of information to global, with all of its connotations and consequences.
– By all these, the position of archaeology and its disciplinary environment is changing. It is linked to other domains of science first with new links, 'bridges', later with wide corridors, connecting formerly closed universes of knowledge.
– The nature of these transformation involves a lot of conflicts, inducing so far unexperienced generational tension, which is fairly difficult to handle with traditional 'rules' of the profession.

The aspects described on the example of archaeology can be 'turned back' to the analysis of general features of the transformation process.

Documentation and simulation of a Roman imperial villa in Central Italy

Ferenc Redő
Archaeological Institute of the HAS

The Roman Period site discussed in this paper devoted to a computerised documentation and modelling experiment is located in Central Italy, at the edge of the Fucino Basin, within the Abruzzo Mountains. Excavations of an Imperial Period villa have been carried out at this site since 1983. The settlement is located within the territory of Alba Fucens, a colonia of long history. The position of the villa and its immediate environment within the hilly landscape is a good example of the esthetical and practical standards of Roman architectural design.

Although the compound itself has not yet been fully excavated, its major blocks are already known, and the owners' elegant residential quarters as well as baths have almost completely been recovered. A number of interesting architectural features, fragmented details of beautiful mosaic floors and painted wall surfaces were found. Their scientific documentation required the on-site description of their positions immediately after the excavation. The need for possible and necessary completion and partial reconstruction has already surfaced during the course of primary data processing. That work represents, however, a new, additional level of documentation. In accordance with the specific characteristics of the site, this meant the redrawing of mosaic floors on the first place. Their geometrical patterns offered a good opportunity for correct reconstruction even in a fragmented state. Since no walls higher than 1 m were preserved at this site, their reconstruction therefore is more problematic and can be carried out only using analogies. On the other hand, the three dimensional modelling of subterranean architectural features offered a promising opportunity for computerised documentation and simulation of the original state.

The work presented here provides the basis of our proposal concerning the site's future.

It is aimed at the modelling of restoration work and development of an open-air archaeological park on the basis of reconstruction carried out using information of scientific accuracy and quality.

Registration and Protection of Fortresses in Hungary

(The topometry and the database of these monuments)

J. Harangozó–E. Marton–Gy. Nováki

In 1969 György Sándorfi an engineer joined the team of researchers observing Hungarian fortresses. He began working on measuring the fortresses while later on he was engaged in the historical aspects of medieval fortresses, too. In the following paper we would like to give a short account on his measuring method.

At the beginning he has carried out land-surveying by the traditional method, that is, with a theodolite. After a long period of experimentation he has developed a technique that allows a simple, quick but exact measuring and gives good results even in dense, bushy forests as well. The points measured on the spot were processed by a computer program that had been developed by his brother-in-law, Lajos Kelecsényi.

One of the authors of the present paper, Gyula Nováki has acquired the surveying technique and has become a permanent collaborator of György Sándorfi. Not long before his death in 1993 he gave his computer program to Erzsébet Marton in order to secure the continuity of the project. After a while Zsuzsa Miklós has joined the team, and since then she also makes use of the surveying method.

Recently specialists of this field have shown interest in this method. The memory of Sándorfi's generous and furthersome character urges us to bring out his method in order to help the researchers of today and the years to come. Field work itself is the same as the traditional survey with theodolite. One has to measure all the essential points that are important from either archaeological or geological aspects. Plotting the contour lines and landmarks will be executed with the help of these points.

While measuring the site one has to make distinctions between main and secondary points. We would start at the 0 main point. Encircling the site by measuring the main points around, we would close the circle by arriving at the 0 main point again. The quantity of the main points and their distance from each other depends on the topography of the site. The maximum range of two points would be less than 30 metres whereas the minimum would be more than 5 metres. After measuring the main points we would measure the secondary points surrounding them. Numbers of the main points will show an increasing series of Arabic numbers. Secondary points have no numbers, since they are indicated by letters. Choosing letters is optional, however it is essential to indicate similar topographical points by similar letters. Here are some examples: 'p' for 'perem' (edge in Hungarian), 'st' for 'sánctető' (head of the rampart), 'áf' for 'árokfenék' (bottom of ditch), 'áfsz' for 'árokfenék széle' (edge of the bottom of ditch), 'ász' for 'árok széle' (edge of ditch), 'k' for 'köröm' (edge of cliff), 'gf' for 'gödörfenék' (bottom of pit), 'HP' for 'helyrajzi pont' (topographical point), 't' for 'terep' (site, the significant point of surface), etc. If remnants of walls, house, well, etc. can be found on the site, we would plot them separately. We shall measure them by band-chain, and shall indicate them by A, B, C.

Measuring: first we shall have to measure the secondary points surrounding the 0 to the subsequent main points. After encircling the site we finish measuring with arriving at the 0 point. The surface will suggest to measure or not secondary points.

Be aware of measuring the same main and secondary points only once.

Neighboring points, less than 3-4 metres, must be measured in north-south direction, rather than in east-west, in order to avoid the error of the computer to print two neighbouring points on the same spot.

Three data must be gained from all main and secondary points:

1. The distance between two main points and between main and secondary points. In order to obtain an absolute exactness we have to measure them by band-chain. We measure according to the inclination of the site and not according to the horizon.
2. The azimuth between two main points and between main and secondary points with the help of a theodolite of high precision.
3. The angle of slope between two main points and between main and secondary points. We gain it by a very simple method, and with the help of a bevel gauge. We measure the divergence between the eye level of our assistant and the absolute horizon.

The computer will calculate the horizontal distance, the co-ordinates of the points and the relative altitude. Having printed the main and the secondary points the contour lines, the archaeological and other objects can be plotted manually and with the help of a squared plotting paper. The contour lines must be given real altitudes according to topographical maps on the scale of 1:10.000.

Because of the great range or the orography of the site sometimes we are not able to measure the area with one circle. We can add further circles. In that case it is important that circles should be closed and attached to the main points.

The development of computers has revolutionised the science of geodetic, and has exempted the data processor from a lot of manual calculations. The new method has given a great opportunity for the processing of fortresses as well. The measured points on the site are registered in record book, then the processing is done by computer. The project consists of calculating the trigonometric correlation on the one hand, and printing the main points, their secondary points, and the relative altitude points on the other.

The innovation of our method is the system of co-ordinates turned round by 90 degree, where the X-axis means South, the Y-axis means East. The fortress and its points will be printed in East-West direction. What is it good for? Because while printing we can use a simple matrix printer, where the bottom of the paper (that is, in the southern direction) is endless, whereas the width of the paper (the Eastern direction) is limited. The printing paper is just like a squared plotting paper. We can print by an optional scale, offered by the program scaled for a maximum 3 sheets of paper. After entering the filename consisting the main and secondary points, the program will offer unconventional scales, depending on our plotting the fortress on one, two, or three sheets of paper.

First example: Patosfa Törökpince. This is a small, round castle with rampart from the Medieval Age.

The first picture (Fig. 1) reveals the main points and the secondary points with their altitude. The scale is 1:250. The map is half-made.

On the picture the finished map of the castle can be examined. The scale is also 1:250. (About the methodology see the first part of this article!)

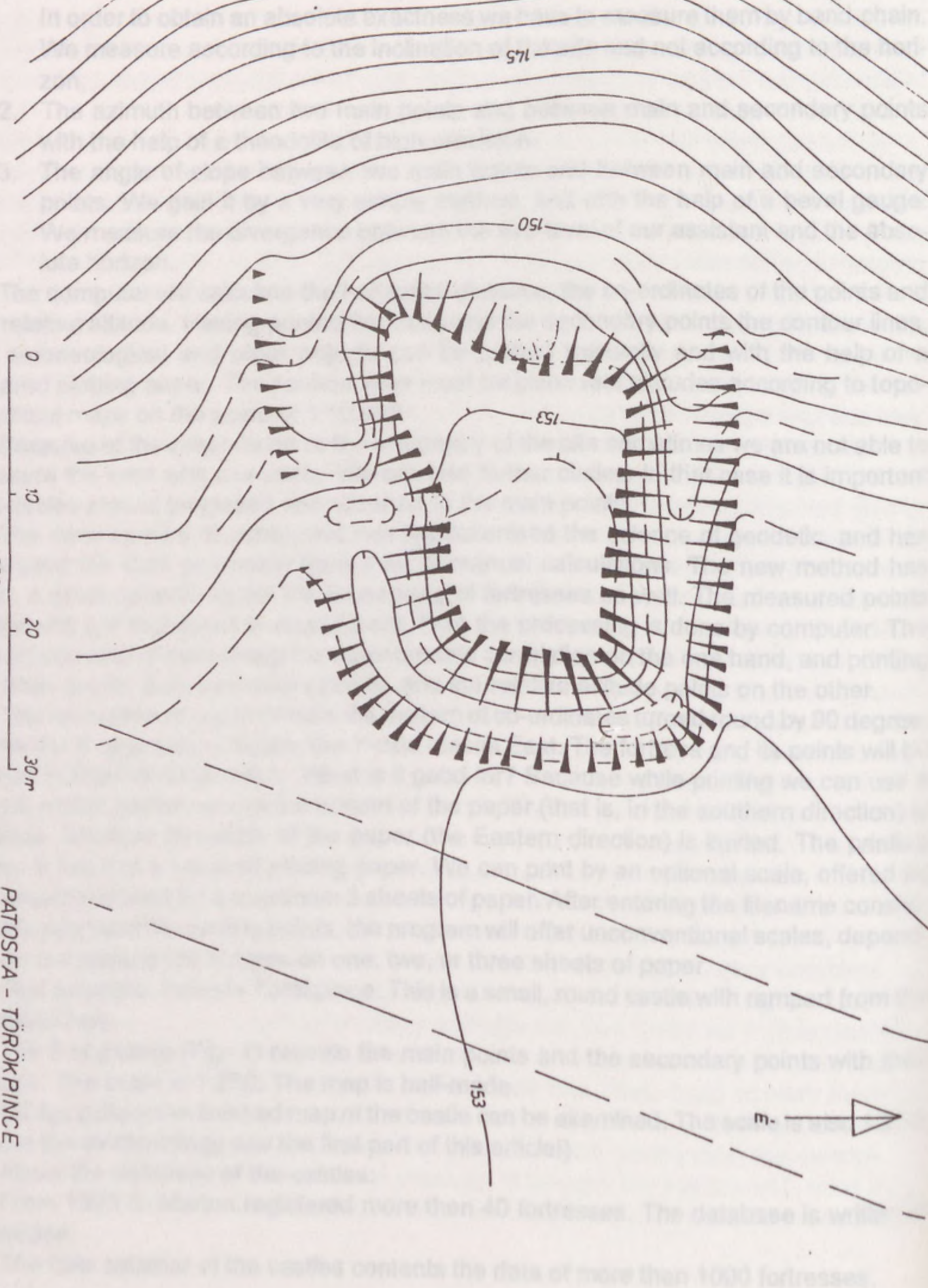
About the database of the castles:

From 1993 E. Marton registered more than 40 fortresses. The database is written in DataEase.

The hole cataster of the castles contents the data of more than 1000 fortresses.

INFORMATION about these castles: Gyula Nováki & József Dénes, Savaria Museum, tel.: (36)-94-312-554; fax: (36)-94-313-736.

For further information about the software please contact E. Marton, Hungarian National Museum, Department of Information: fax: (36-1)-210-1338; e-mail: h10462mar@ella.hu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PATOSFA - TÖRÖKPINCE
Felmérte: Nováki Gyula 1994.

Was the "look" of the dead or the position of the body decisive in the burial rite in the late neolithic age?

Ida Bognár-Kutzián–Katalin Barlai

In our previous publications we have attempted to find an answer to the problem: what was the aim of the orientation of the skeletons and graves in neolithic cemeteries. We concluded that the yearly path of the Sun was the basis of orientation, taking into account the geographical latitude.

The orientation of the remains found in ancient cemeteries raises the question whether the axis of the body, that is the orientation of the skull, is the decisive factor only, or did the direction in which the face was made to "look" also play a role?

We have assumed that these aspects of the ritual were defined by the movement of the Sun. In the light of this assumption we examined the orientation of skeletons found in two burial sites of similar age belonging to different cultures. One cemetery, found at KISKÖRE (East Hungary) belongs to the Tisza Culture, the other, at VILLANYKÖVESD (Transdanubia) represents the Lengyel Culture.

Our results at present seem to indicate, that for the Tisza Culture the direction of the body, that is the skull was the basis of orientation, while the dead of the Lengyel Culture had their faces pointed towards the Sun.

Algorythmic data analysis in archaeological research

Gábor Rezi Kató–László Újlaki***
* Hungarian National Museum
** Active Record Software System

Motto: In algorithm it is always the most important dimension that has the biggest chance to be left out.

The informatical revolution as well its indirect consequences in the development of specific scientific branches has brought about significant development in the research and analytical methods of archaeology as well. Apart from projects of interdisciplinary character, special fields became independent within archaeology, like GIS and the application of quantitative methods. They have contributed with their special tool kit to traditional research, widening possibilities, but also brought about the specific problems of their original scientific field. The aim of this paper is to raise problems concerning a special type of application, i.e., seriation and delineate within rational frames a system which can handle arising problems in an algorithmic way and direct further steps of analysis. Among the mathematical methods applied in archaeology, seriation procedures have a distinguished role. Sequential ordering on the basis of closed find assemblages like graves has already substantial literature. In the practice of seriation, one of the key problems is the selection of characteristic elements, i.e., the separation of types. Neglecting the differences between types in archaeological concept and that of seriational types can result in serious mistakes. One of the important elements of seriational types is the analysis of the formal characteristics. One of the important areas of research is collating traditional terminology with the types separated by mathematically supported morphological analysis. Cluster analysis is also frequently used for this purpose. Multidimensional grouping, however, cannot solve the original problem, i.e., selecting the really important discriminative features. In our experiences, the groups formed in multidimensional space will not clarify the classification of originally problematic cases. Therefore it seems reasonable to use other methods which may help in solving this problem. For example, the use of neurone networks may be perspective in this field. Opposed to traditional classification systems, neuron networks are 'associative' which means that they can be used for tracing hidden patterns (e.g., Kohonen-self organising maps). Neurone networks also support the classification of problematic cases. Archaeologists may find the program Gerenia, using the Classitron algorythm, useful for their work because it requires no special preparations, is fast and able to teach itself, and suitable to work on large amount of input data. The network gives a fast response to working hypotheses and their elastic modification. An iteration connection of different methods - seriation, cluster analysis and neuron network - is considered as a possible working hypothesis which may point further than simple tasks of ordering. Accepting or rejecting this hypothesis is the subject of current tests.

The revolution in computer technology - like in the case of other sciences - has brought forward significant changes in the methods of archaeological research analysis. These disciplines that were regarded as auxiliary sciences earlier, has now turned out to be important means of archaeology not only with their results but also with their research models and methods. The disciplines have radically transformed the social science in its aspects and traditions. Besides the interdisciplinary kind of research, certain special fields have practically become independent, expanded the possibilities of archaeological research with their particular means, but at the same time they have brought along the problems of their own fields. As a result of this process, in many cases the questions emerging during research are now separated from archaeological aspects and they put the possible solutions of problems into another dimension. During the analysis of the algorithmized input data that have been digital and transformed from the reality of archaeology into the area of mathematics we use the help of machines the work of which is based on the principle of a black box. In this kind of black box the choice of the input data, the operations performed on them cannot be interpreted on historic ground and usually only the final output data can be analysed. This method makes it possible for someone to alter the input data and the operations - without any control and interpretation - up to the point where he gets only those results that are appropriate to him. The aim of this lecture is to set up the plan of a system based on the analysis of those questions and problems that may emerge in a research application, that is Seri system - within rational boundaries - can algorithmically handle problems of a rather mathematical nature, can help the researcher in stepping forward and can offer a larger scope in controlling and modifying the process, all based on possibly exact and measurable data. We have to emphasise, though, that there is no such an algorithm that can work lacking the necessary human expertise (mathematical and archaeological). Among the mathematical statistical methods and user programmes applied in archaeology today, seriational procedures have really high proportions. The chronological systematisation based on the characteristics (findings) of closed archaeological units (usually burials) has a large variety of special literature. This applies both to the theory of seriation and to the practical application, the circle of concrete implementations. The literature concerning the theoretical and practical parts abound in the possible and typical mistakes that occur during the application of striation (the separation of male and female graves, the analysis of social status etc.). In this case of seriational type formation, however, which is one of the most important among the possible sources of mistakes, there is not a method that could prevent the researcher from making mistakes. In this case, according to common practice, one can only try to make experiments or to alter the input data. This method is supported by the programs too with the help of in-built utilities.

The formation and modification of seriational types is a typical moment of the black box effect mentioned above. It is not new that the definition of the exact types is very difficult but the problem that has been culminating since the appearance of the application of computer technology is in close connection with the research problems of two sciences involved, namely archaeology and computer technology. Ever since the beginning of archaeology as a science its most important work method has been typology, that is a system that groups the phenomenon into different types. The traditional typological systems usually describe the formal and chronological development on inner archaeological inheritance of a certain culture, group or facies etc. The development of this typological systems usually takes a long time depending on the growing amount of the already known findings. The refining and developing of these typologies regularly slows down after reaching a certain quantitative and qualitative level. Usually these systems are very subjective from many points of view; a fact that can mostly be observed when those types that are being defined here serve as input data for more serious analytical investigations. No wonder that with the spreading of computer technology, researchers had high hopes with the development of numerical taxonomy and of an exact typological system. However, nowadays this process is in its early state. One very important reason for this is that the development of this kind of application is not an easy problem despite the high standard of computer techniques. The MI research that serves as a necessary background in the development has been in a grave crises for a long time.

The knowledge based expertise systems favoured in recent decades did not fulfill the expectations. One of its consequences is the fact that the use of shape recognising and classification methods are not that open to social siences so that they could bring radical changes in research. As far as our special field is concerned, our situation could be defined as follows: we have stepped over the point where coded and formal systems were developed to describe the shape of objects but we have not reached a level where the recording and digitalizing of the data necessary for the analysation could totally be automatized. The researching and developing of typological systems do not at all belong to the tasks carried out by computer technology. For the time being we have to work with the given possibilities or to point out the direction of prospective research. Turning back to our original hypothesis we would like to create such a system plan where the creation of the typological system is the result of a controlled and exact process based on measurable data and where the properness of the typological system can be controlled with the help of archaeological knowledge and other indicators. The main principle of this system is an international method that could be devided into three basic (theoretical) parts:

1. The preparation of data. Digitalising, the choice of a characteristic, type definition
2. Seriation
3. Result checking, modifying

The first point involves the most neurological factors.

a) **Digitalisation**

At the level of the the technology today the archaeological information sources, which are likely to be already incomplete, are coded and this coding involves the losing of data. At present, even the most perfect 3D digitalisation cannot be complete, cannot comprise everything (e.g. colour, material quality, burning etc.). This process is very time and labour-consuming supposing that it wishes to concentrate on the necessary completeness. The possibility and the practical appearance of losing data is significant even at this level.

b) **The choice of a characteristic**

One possible means of creating an exact type is the application of such a grouping algorithm that can help to give the classdefinition. Today the most widespread form of this is clasteranalysis. In this case, however, we have to choose the characteristic features of the species getting into the analysis from the digitalized and coded database in such a way that in the hiperspace the groups of species defined by their characteristics as co-ordinates form classes that are suitable for the aims of the grouping.

The problem of the choice of the characteristic and the grouping is wide and far-reaching, and in the aspect of the given application it has to be approached on the level of basic research. During the practical application, the setting up of the system and the process of testing it was obvious that the use of the clasteranalysis is a necessary but not sufficient condition in the creation of types. The characteristics, the choice of the proper methods and the interpretation of data is a highly problematic and time consuming procedure. It' s difficult to choose the characteristics so that we can work with an appropriately high number of dimensions which gives a better possibility for the separation of different classes, and at the same time to enforce properly the proportion of the characteristics in the classification in accordance with their significance. Therefore, it seemed expedient to apply such a further method that can help to solve these questions. In 1993, on a conference called " The future of our past " a neuronsystematic software was introduced. It uses the Classitron algorithm and is hoped to play the role of the further method mentioned above. As opposed to the traditional classing system, the neuron network systems have such abilities that stand very close to human associative. This may mean a solution to the often very uncertain classdefinition of the clasteranalysis. In our opinion the neuronnetwork recognition that uses the results of the analysis could help the researchers to classify those uncertain species where classdefinition cannot be decided on the basis of clasteranalysis. Obviously, in this case the controlling of these types will be the measure of the properness of the chosen characteristics, though it will be the task of practical testing to point out whether the same characteristics have the same effect both in the case of clasteranalysis and in the neuronnetwork system.

c) **Type definition**

Apart from the above, at this stage we have to deal with the question, namely that during the formation of such typologies we have to stress the importance of the fact that the seriotional typology and the traditional archaeological typology system, the types and class types set up in them in the most case do not cover one another entirely. (Here it is enough to refer to those obvious and well-known differences that from the point of view of seriational typology, we regard, for example, a chronologically characteristic rite a type, but at the same time we have to interpret a traditional archaeological type differently if it has such a characteristic that can get - though incorrectly - a chronological dimension if it gets into the algorithm. (e.g. male - female finds). *Hence, the archaeological and seriational type is not the same, we define them as follows:*

The archaeological type is usually a group of objects which, in the first place, is a class of species belonging together on the base of their form. The typology used here groups the observed species into types based on their characteristic shape marks. As opposed to this the seriational type has only chronological importance, the species of the group belong to a time interval that can easily be defined, the species do not exist outside this interval and there aren't any other seriational types whose time interval would be the same as the original interval. According to the definition it is obvious that a paradox may arise, namely that from the point of view of seriational typology we can regard two, archaeological different groups of object as the same, if the time interval of the existence of their species is the same. One - but not the only - reason for the difference between the archaeological and seriational typology is the fact that in contrast with archaeological typology, the typology here refers not only to one object but to the characteristics of a whole archaeological unit. The separation of seriational and archaeological type, their rules require further research, nevertheless, we should accept the introduction of concepts as basic axioms in the field of seriation. Though, as far as the subjects of typology are concerned, the obvious differences in the concepts can be interpreted on the notional level of archaeology and typology, still in my opinion the concepts that were introduced are in relation with the archaeological types, too. Without precise definitions I can see this effect in the distinction between a static and dynamic typology, where the difference between the two systems is made with a more significant stress on the fourth, i.e.. time dimension.

2. Seriation

The seriation of the given findings can be done with the help of the typeclass set up in no. 1. From the existing programs, we use the "Bonn Archaeological Statistics Package" which gives the user a firm analysis of the results and in the comparison of the running test results. It enables us to check the properness of the defined types and to do the calibration with the help of cemeteries the chronology of which can be grasped easily.

3. Checking of the results, modifications

On the one hand, the checking point in the iterative system can be the evaluation of the seriational results, where we can check the type definitions gained from the mathematical way with the biggest probability. On the other hand, another possible way of checking can be the use of a simple statistics where we can follow the changes in each class in the light of the input data. (The modification in the number of the classes the modification in the number of the species in the classes, the species' class modification) Software implementions used in the system:

1. ArchiCAD data-input system which is suitable for digitalizing the metric data of objects
2. The Bonn Archaeological Statistics Package
3. Gerenia neuronnetwork software 4. SERPA conversational evaluative program

We regard the system-like connection of the clasteranalysis used in seriaton analysis as a possible algorithmic hypothesis which in many aspects exceeds the solution of an organising task. The proving or the rejecting of the hypothesis is the task of the testings that are in progress now.

Dendrochronological study of the Roman wells found during the rescue excavations of the Ménfőcsanak-83 road

Andrea Vaday–András Grynaeus***
* Archaeological Institute of the HAS
** ELTE University, Dept. of Medieval Archaeology

During the years 1993-1994 rescue excavations were performed on the treck of the motor way Nr. M1 and the conjoining road 83, outside the village Ménfőcsanak. On the 2 km long and 40 m wide excavated surface settlements from the following periods were found: La Tene B-C-D (celtic), Roman, migration period and period of the Árpád dynasty. There were four different types of wells found on the settlements. Apart from simple shat wells with stone lining we have found wells with wooden lining as well. A part of the latter were made of timber-work. In case of another type the lining of the wells were made of Roman barrels as secondary utilisation. We are in the initial phase of elaboration's yet. Thus only the observations of the timber-work wells will be treated here. The study of the timber-work Roman wells at Ménfőcsanakon is specially important, because this site yielded the first large series suitable for a dendrochronological analysis in Hungary. The importance of the material is increased by the good documentation of find circumstances. During the excavation 7 features were found which contained the remains of timber-work well lining. In all instances, they were made of oak. Altogether 52 samples could be taken. The thickness of tree rings was recorded in two directions on each sample. On the basis of these, the average thickness series of rings was calculated. This was followed by the comparison of samples coming from the same features, and finally, the series of the individual features were compared. During comparison, correspondence values higher than t = 5 were considered identical, which is higher than the routine European practice). As a result of our investigation, a dendrochronological series comprising 276 years could be set. Within this period, the wells were made in two periods: the first (feature nr. 585) was made around the 130th year of the period, the second period (comprising features 37., 99., 137., 249., 355.) was made by the 260th-280th year. Data from feature 531. could not be fit in the series. This can be explained by two reasons: either it was made in a different period, or the wood used for lining was transported from distant areas. Comparing our data to the South-German series we can give absolute dates to our features.

Acting on this hypothesis, we have to face two problems:

1. the correspondence values are over European average but below our more rigid criteria. This can be explained by the marginal position of the site.
2. accepting our hypothesis, the validity of the South-German oak chronology zone was larger in the Roman times than today which can be possibly explained by climatic features.

Analysing the interior periodisation of the individual features, several periods could be separated within the structures. These differences can be estimated for several decades and explained by secondary use of timber in the wells. Further research will be devoted to the exact taxonomic analysis as well as testing the correspondence with South-German chronological series by different methods.

Antecedents

Ménfőcsanak, an administrative part of Győr (W Hungary) was the locality of several major rescue excavation connected with road construction and related investments. The first rescue excavations were performed at the Northern exit of the M1 motor way towards the city in 1990–91. During 1993-94, the phase of road 83 avoiding Ménfőcsanak was prospected and excavated. In 1995, the rescue excavation of a supermarket area was started along the road on a surface of nearly 10 ha. Already during the excavation of the Northern roundabout, wells were observed, among them wells with wooden construction. On the place of the shopping centre several wells were excavated, among them some with wooden lining. During the 1993-94 season, there were two types of well observed along the road 83, namely wooden construction made of timber by carpentry and wells lined with former tubs. Both types were registered from Hungary previously. In 1911, earthworks of the Óbuda Gas Factory unearthed in the depth of 5-6 m wooden remains originating from Roman wells. These remains were elaborated, abart from archaeological study by botanists as well. In 1975, another tub lined well was unearthed Aquincum. Xylothomic study of the latter was also performed.

Apart from relative dating based on stratigraphy and the typology of the finds, scientific methods of dating could be applied. Already in 1993 it was supposed that the tubs were containers for import goods and in this case it provides an exceptional possibility for collating dendrochronological data from the territory of Hungary and wider regions of the Roman Empire. In 1995 fortunate finds supported our former hypothesis. We could find inscribed tubs which proved that they were bona fide imports and also we could find wells where the local timber occurred together with imported tubs. It is stressed that this paper is meant as preliminary result of analyses where the study of the timber of carpentry made wells excavated in 1993–94 is presented.

Biological principles of dendrochronological dating

In the temperate climatic zone as well as all regions where seasonality can be observed, the growth of wooden matter in trees is uneven. The kambium phase (the exterior part formed of dividing cells) and growth rings called tree-rings can be easily separated. Counting the tree-rings we can calculate the age of the tree in the time when it was felled. This is only the 'lifetime' of the tree and not a dateable age. There are arboreal species with genetically wide tree rings (like poplar), and trees with narrow rings (e.g., oak).

The thickness of subsequent rings is different and has no direct periodicity because the thickness of the rings depend on, apart from species and locality and density of the forest but also external factors (precipitation, temperature, insects etc.), different from year to year.

These factors are complemented by extraterestric factors, in the first place sunspots which is reacted by the different species in different ways. While spruce (?) jegenyefenyő (Abies alba Mill.) is most reactive to this factor, oak is hardly affected. The combination of these factors prevent the changes from being periodical. In a series of more than 30 rings we can be certain that the pattern of tree ring growth will not occur similarly in the life of the species, i.e., it is historically unique. This is one of the basic principles of dendrochronology, the so called historical principle.

The changes in tree-ring growth in case of two or more trees is similar, provided they belong to the same species, and they were living close enough to each other to benefit from the above factors equally. This statement is also true from the other side: if the thickness of rings on the trees is similar, they are contemporaneous. This is the second basic principle of dendrochronology, the principle of synchrony.

By this "overlapping" technique we can construct a tree ring thickness sequence which is characteristic for a given species in a given area and penetrates far into the past (Fig. 1.).

When finding a tree-trunk of unknown age, we only have to find the matching phase of our chronological sequence. If all tree-rings of the unknown piece of wood fits into the range of dateable range, the plant fossil is adequately dated.

The advantage of dendrochronological dating compared to other methods, e.g. radiocarbon dating, that it is very cheap, and with a little luck it can give very accurate dates, even within a given year. Therefore quite fast after the elaboration of the method it was effectively used in archaeology, first in the USA, but more and more extensively in Europe as well.

Limitations of the method are also inherent from the biological principles it works upon. The identity of species within a given region should be previously compiled and only remains over 30 rings are suitable for study. The region it can be used effectively varies: e.g., in Southern Germany oak trees behave according to similar patterns in a circle or cca.1000 km diameter while in Northern Germany, a new chronological sequence should be compiled for regions 100 kms apart.

The process of dating

The analysis starts with sampling which can be performed by sawing the complete section or boring in a radial cut by a special instrument. In case of panel paintings, no special preparation is needs. The study of a full section gives more exact results, therefore the average of four radial sections is preferred to one sample.

The bark of the tree protects the productive cells situated under the bark. Moreover, it has decisive role in water transport towards the leaves. 'szíjács' is the living part of the tree-trunk, transporting nutrients to all cells of the tree. The 'geszt' is not taking part in the life processes of the tree, 'only' supports the plant by the halp of the accumulated material.

All these are important for dating because the thickness of szijács is permanent depending on species and area, the productive cells (kambium) creates new rings annually while the innermost ring of the szijács turn to geszt, its pores get filled with geszt matter. Thus the szijács part, with constant tree ring number is moving towards the bark as the tree is getting thicker and more aged.

Knowing the thickness of the szijács, we can estimate with considerable accuracy the age of the tree when it was felled or the earliest possible date for this event (Fig 2.).

The site at Ménfőcsanak, 83rd road

The study of the carpentered Roman wells at Ménfőcsanak, 83th road is specially important as the first site in Hungary which was suitable for the dendrochronological analysis of a large sample. The importance of the material is increased by the fact that all items were fully documented.

During the excavations 6 wells were found which contained remnants of carpentered wooden lining. Apart from these, wells lined with tubs were also found, the analysis of which is in progress.

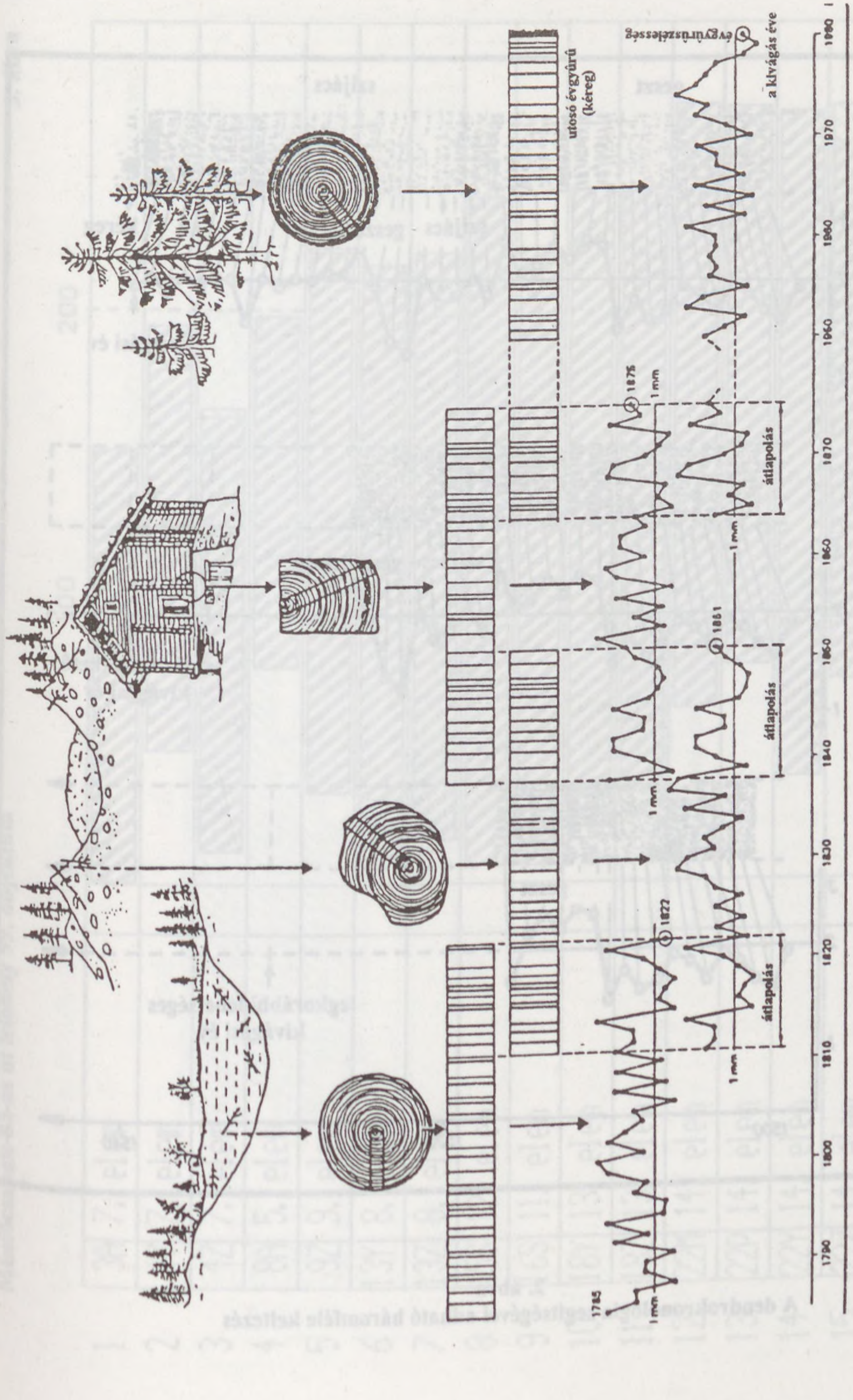
All of the timbers used for the wells were oak. Further studies may aim at a more exact taxonomical determination. From the logs brought to the surface, altogether 52 samples were selected. more exactly, sewn, for analysis.

In course of the analysis the thickness of rings was measured in two directions for all samples, as we had only one slice from all sections. After this, the average tree-ring thickness was calculated within the same features (Fig. 3.) and the series characteristic of these features was calculated. The sequence of the wells was compared after the individual feature ring thickness series were established. By comparison we were selecting more rigid similarity indices than usual for European data, i.e., where t values calculated by statistical analyses were higher than 5. The statistical calculations were made using CATRAS-EDIPLOTT software package. The program was bought from the support of the National Science Foundation Grant (OTKA).

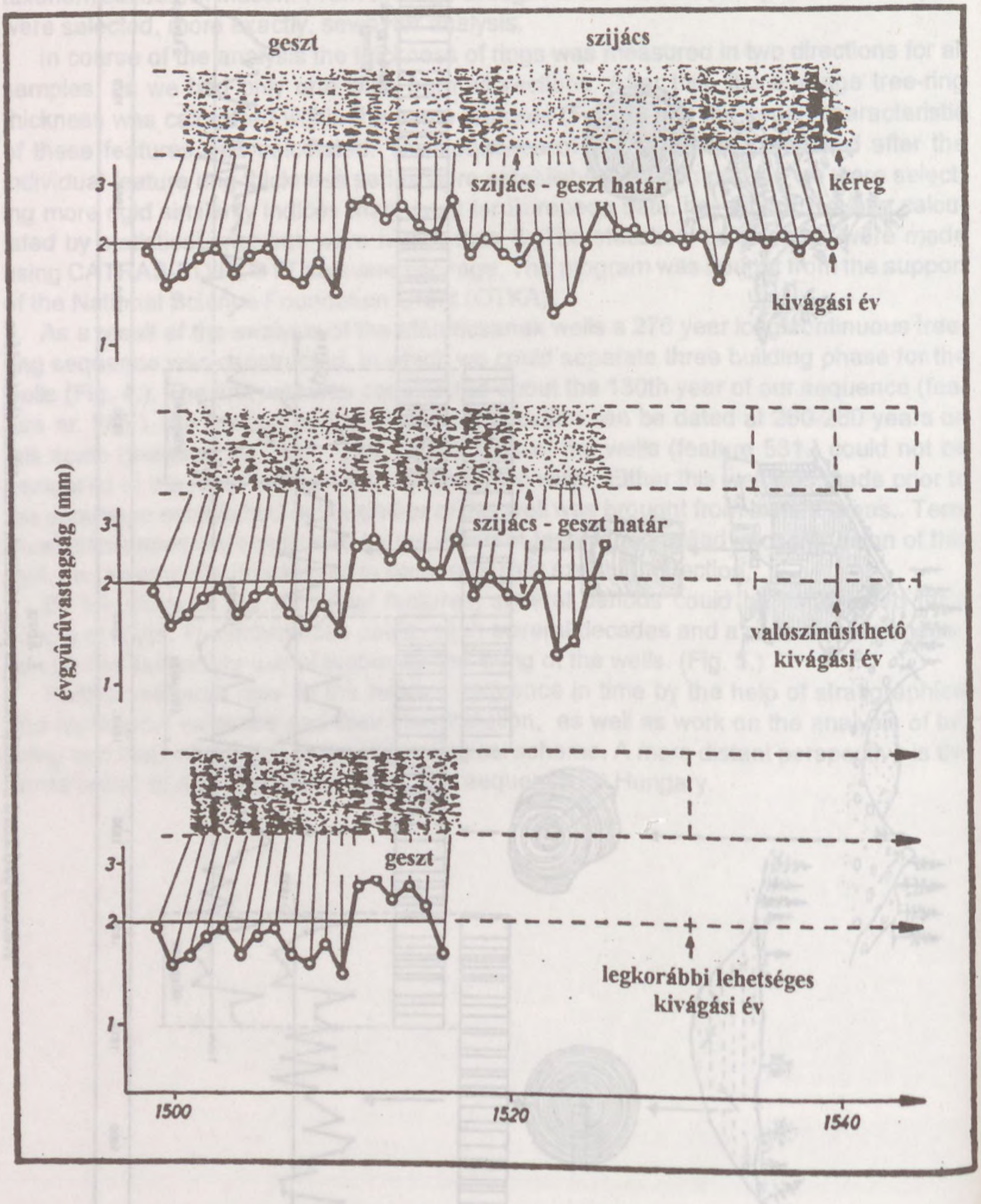
As a result of the analysis of the Ménfőcsanak wells a 276 year long continuous tree-ring sequence was constructed, in which we could separate three building phase for the wells (Fig. 4.): The first well was constructed about the 130th year of our sequence (feature nr. 585.), the second period of well-construction can be dated at 260-280 years on this scale (features 99., 137., 249., 355.). One of the wells (feature 531.) could not be compared to the rest. This can be explained two ways. Either this well was made prior to the sequence established or the timber of this well was brought from distant areas.. Temporal differences were indicated by the different technique applied in construction of this well, i.e., sawing not inradial but in tangential (húr szerinti) direction.

By the study of the individual features, several periods could be established for a couple of wells. The differences could reach several decades and a possible explanation can be the secondary use of timber for the lining of the wells. (Fig. 5.)

Further research may fix the relative sequence in time by the help of stratigraphical and typological evidence and their interpretation, as well as work on the analysis of tub lining and their integration to the chronological scheme. A more distant perspective is the construction of a full dendrochronological sequence for Hungary.



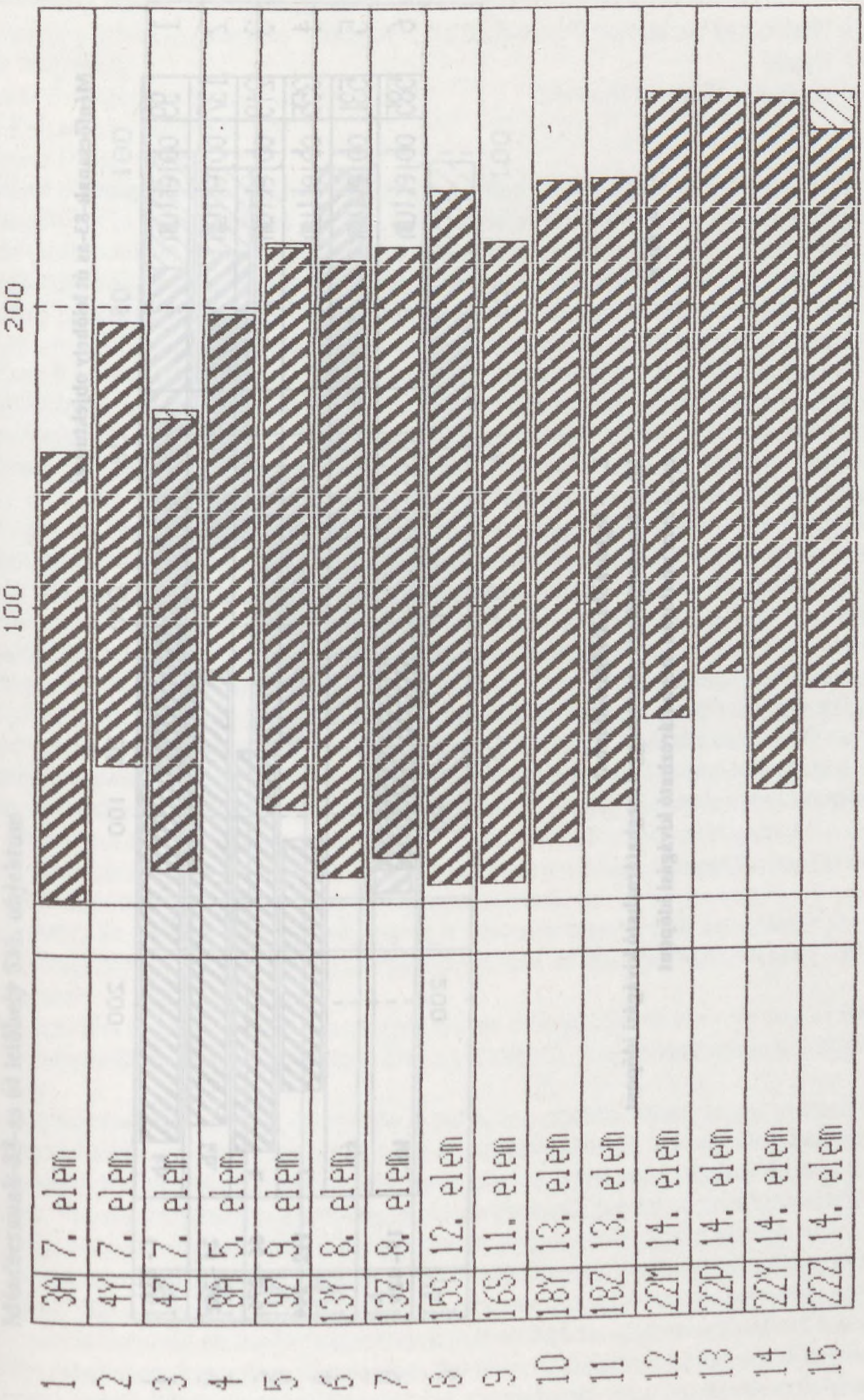
1. ábra
Különböző korú minták összekapcsolásának sematikus ábrázolása



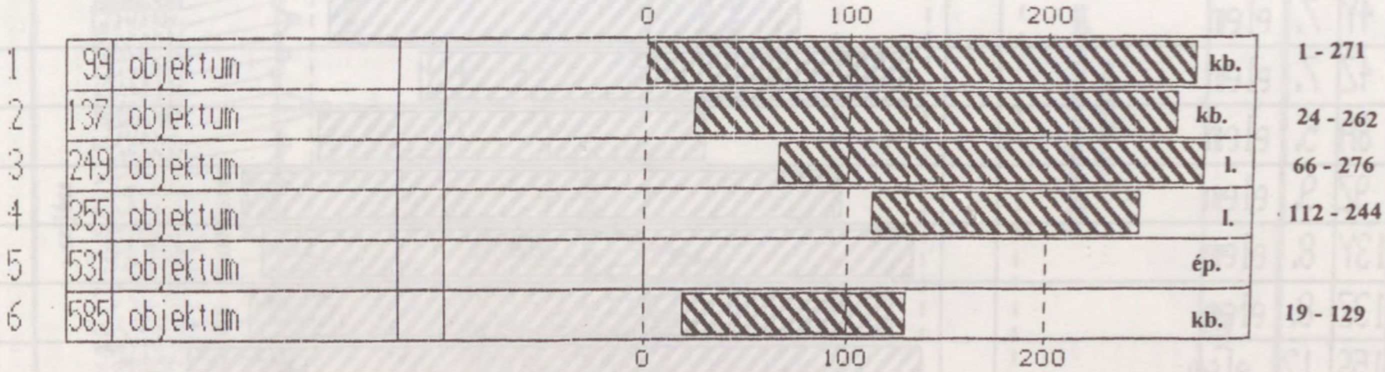
2. ábra
A dendrokronológia segítségével adható háromféle keltezés

3. ábra

Ménfőcsanak-83-as út lelőhely 99. objektum



Ménfőcsanak-83-as út lelőhely objektumai



4. ábra

l. = legkorábbi kivágási időpont

kb. = hozzávetőleges pontossággal meghatározható kivágási időpont

ép. = évre pontosan meghatározható kivágási időpont

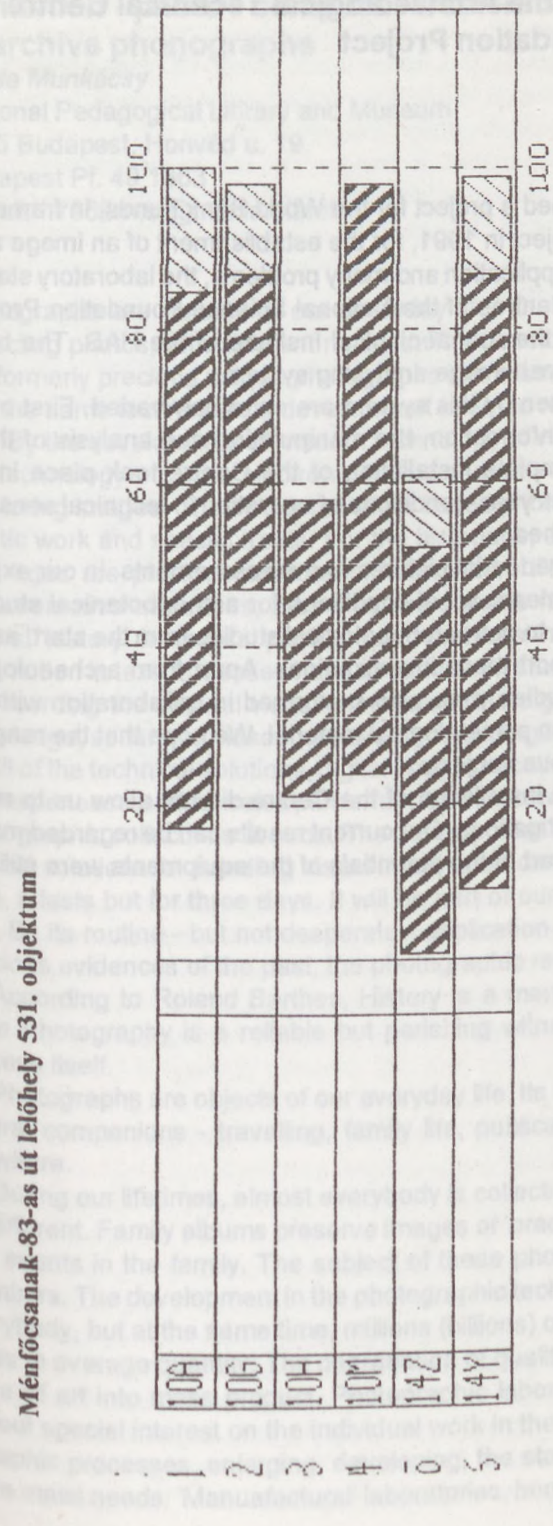

Ménfőcsanak-83-as út lelőhely 531. objektum
5.ábra
20
40
60
80
100
10A
10G
10H
10M
14Y

Image analytical analyses in the Archaeological Technical Centre of the National Science Foundation Project

Ferenc Gyulai
Archaeological Institute of the HAS

A team of eight specialist had launched a project for the World Bank Funds, in frames of the National Science Foundation Project in 1991, for the establishment of an image analysing laboratory. After a successful application and many problems, the laboratory started its activity as one of the Technical Centres of the National Science Foundation Project. The host institution of the Centre is the Archaeological Institute of the HAS. The basic element of the laboratory is a Macintosh image analysing system.

The tasks which can be undertaken by this system are extremely varied. First of all, recording of a wide range of visual information, the manipulation and analysis of these images can be performed. The complete installation of the Centre took place in the second half of 1994. By the end of this year, conditions of operation in technical sense as well as basic expertise were established.

During the learning process we made trial pictures and measurements. In our experience, the equipment of the Centre means ideal conditions for archeobotanical studies. Also, we attached special importance to petroarchaeological studies from the start, as the composition of the equipments support these investigations. Apart from archaeological material, traditional mineralogical studies were also performed in collaboration with the Hungarian Geological Survey, e.g., on planetological material. We hope that the range of analyses can be extended over various subjects.

The short time elapsed since the installation of the Centre did not allow us to make large project and large series of investigations. Our current results can be regarded mainly as learning examples in which only part of the potentials of the equipments were utilised.

Exhibition - photo - computer - restoration of the content of archive phonographs

Gyula Munkácsy
National Pedagogical Library and Museum
1055 Budapest, Honvéd u. 19.
Budapest Pf. 49 1363
E-mail: h7966mun@huella.bitnet

Photographs are objects of our everyday life. During our lifetime we are continuously collecting photos, with different motives. The development of photo technology changed the formerly precious unique photographs into mass products. It is a starnge twist of fate that the same technological development seem to restore the special status of photography. By the development of modern technology of visual recording like computer images, CD technology etc., the electronic media seem to replace photographs as mass media for storing images. The traditional silver based photographic material will be reserved for artistic work and special treats. For the historians, all the visual and audio information of past ages are precious sources of information. Photographs have a special value as documentative evidences; thus they are suitable for the analysis of 'private' as well as 'official' history. In several photographic archives the process of recording photographic information in text databases have already been started. Apart from this, efforts are made for recording the original visual information, the digitalisation of the images. To my best knowledge, so far two museums have formed image archivation and processing systems. As all of the technical solutions, digital image processing had to survive the initial mistakes of inexperience and hurrah-optimism. It cannot solve all of our problems concerning the photographic collections at once. The development of photographic technology and informatical solutions for handling visual information can impress the layman, but as all wonders, it lasts but for three days. It will be part of our everyday museum work as a useful tool. By its routine - but not desperate - application it can help to lengthen the life of our precious evidences of the past, the photographic record.

According to Roland Barthes, History is a memory constructed by special recipies while Photography is a reliable but perishing witness of the symbolic 'durée', i.e., the process itself.

Photographs are objects of our everyday life. Its different forms are met day by day as natural companions - travelling, family life, publications and advertisement, practically anywhere.

During our lifetimes, almost everybody is collecting photos, however, our motives can be different. Family albums preserve images of 'predecessor' as well as offspring', important events in the family. The subject of these photos have value mainly for the family members. The development in the photographic techniques rendered photos available for everybody, but at the same time, millions (billions) of non-professional photos resulted in a loss in average quantity. The degradation of quality transformed the valuable individual piece of art into mass product. Photographic laboratories work on pieces after pieces, without special interest on the individual work in their hands. Automatisation of the photographic processes, enlarging, developing, the standardisation of cuts are designed to serve mass needs. 'Manuafactural' laboratories, home hoppy labs are used partly to overcome this trend. In a contradictory way, the mass product character of photographs are seemingly changed by the same trends, i.e., technical development. The gradually spreading digital images, storage in image files, video tapes, Photo CD and the like seem to overtake the market of mass production in due time while traditional silver-based photography will be preserved for artistic photographic images.

For the science of history, all written materials, images and sound records have some information left by the ages passed. Photographs are special elements as sources of information. Detached from the context of other sources - i.e., 'collected' by museologists, collection keepers or librarians and 'described', interpreted for collection inventory purposes, they are turned to historical evidence.

For a long time, historians mainly used photos as illustrations. For modern research, however, other aspects of photos as sources of information became evident. Photos are typically void of language barriers and as such, they are suitable for general historical comparisons. Placing images side by side, our analyses can be independent of time and space, see the development of centuries, changes in the environment, the material culture, costumes or social structure, thus offering a primary source for anthropological research in the widest sense. Photos have a documentative value: they can be used for matching 'written' history to anybody's private experiences, history as experienced by the ego. Certain theoreticians of the subject regard photos as the catchment of the minute, that of reality and as such, having a documentative value. Others tend to think that the photo is immediately detached from subject and reality in the moment of its origin and starts an independent new existence, which is a strange mixture including the subject of the photo, the 'eye', i.e., vision and ideas of the photographer and the object having real physical properties in a real world with size, colour, material and preservation - and this latter aspects are the qualities treated by museology.

Digitalisation of photos and storage on CD-s

In a growing number of collections the processing of photographic images has been started as textual databases. The archivation of images and related database development was started so far, to my best knowledge, in two collections: The Hungarian Photography Museum (Kecskemét) and the National Pedagogical Library and Museum.

Development of the graphic workstation of the National Pedagogical Library and Museum

Hardware:

486DX-2 66MH, 24 MB RAM, 220 MB IDE HDD, 1.4 MB and 1.2 MB FDD, SCSI interface card, Plextor 4x SCSI CD-ROM

1.4 GB external HDD

Diamond Viper 4 MB VRAM video card

Philips 17" FlatSquare Autoscan colour monitor

AGFA ARKUS II. 600 x 1200 dpi colour scanner

Software:

DOS 6.22, WINDOWS 3.1, PhotoShop 2.51, PhotoLook, PhotoTune

The above configuration was designed for tasks of image archivation. The primary conditions were the selection of a fast and reliable computer with large RAM as the processing of the images require large memory. At the same time the storage demands of the high resolution true colour images required a fast and large hard disc. The type of scanner had to be selected with special care, because most of the commercial scanners use harmfully strong light in scanning the image surface. The AGFA scanner selected has a low UV radiation 4 W fluorescent ligth tube. Also, the AGFA scanner scans the image in one 'run' while concurrent solutions use three runs. This type is suitable for the recording of both positive and negative as well as transparent and refractive images including colour negatives and slides.

The acceptable presentation of digital images is also an important point. Let me refer to professional retouch and use of images in exhibition. Therefore a 17" SVGA monitor was selected for the equipment.

It is important to note that during the digitalisation of the photos the technique of data input is different from traditional photography and does not replace the photo itself. Its resolution, colours, appearance are totally different. Manipulation of the digital image can help in creating a similar look.

As Vilem Flusser commented on the photos, the photo, as an object is almost worthless. Its value is not in the matter but in the information on its surface. By a cheap and easy way of reproduction and digital recording this information may loose its singularity. These observations seem evident, but the relation of everyday persons to digital images and photos is different. As all technical novelties, digital image technique attracts irreal exoectations. It is certainly a great possibility but it will not solve all problems concerning the collections.

Scanners

A prerequisite for digital image processing is to feed visual information into the memory. Scanners are specially designed to computerise slides, negatives, and positive photographs.

They can be divided into four distinct types: "dob"scanners producing printable copies. These scanners fix the original image on a cylinder which is rotated with high speed. The sensor reading the image is moving on a linear course. Such equipments are very expensive but the resolution which can be achived by them is several thousand dpi. "Lap"scanners developed for Pcs are less expensive and therefore they are available for the museum public. In these equipments the photo is placed on a glass plate under a cover. The reading head moves on a linear scale under the glass reading information line by line. Their resolution is typically between 300 and 1200 dpi which can be further enhanced by special software. The size of the image can be A4-, or even A3.

The third large group is hand scanners. They work similar to "lap"scanners. The width of reading is 10-12 cm, therefore larger images can be fed in several runs. Their maximal resolution is 100-400 dpi. Due to these limitations, they are ill suited for l image processing in museums.

The fourth group of scanners is "dia"scanner. These were developed to read slides or negative films into the computer. The mechanism of reading is somewhat different from the previous groups. The resolution of "dia"scanners can reach 2000-3000 dpi which is necessary given the small size of the original image. This small image is enlarged to the size of the screen, which is a decrease to resolution. Its use in museums is also limited by the standard size input to the sanning mask (e.g., 35 mm film).

CD technique

The fast spreading of CD-ROM drives induced a growing interest in devices suitable for 'recording' information on CD. By the help of special hardware and software, on one disk 650 Mbyte information can be stored including data backup and multimedia applications. The storing capacity of a single CD equals 1500 floppy discs or 250 000 printed pages. There are competitive solutions like WORM drives or bernoulli discs, but they require an external drive and more expensive media.

Possibilities of image digitalisation and CD-technique in museums

Archivation

Digital images stored on a CD mean most in the archivation of images. Traditional inventory practice employed a small size black-and-white positive on the objects, sticked to its inventory card. Archivation by computers stored on CD can be fast and cost saving and can fully replace documentative photos.

Exhibition

Apart from original museum objects, so-called. multimedia applications can be used extensively in exhibitions. Its novelty lies in interactivity, which gives a possibility for visitors to explore information sources at their own need and pace. A well designed image, vaoice and text system can be a great attraction tho visitors. Additional information can be included which can match scientific publications and handbooks or, due to their concise character, they can offer even more. Multimedia shows can be one of the effective means of exhibitions in the near future, e.g. projected by 'Beamer'.

Preservation of the original

By the use of textual and image databases everyday museological work as well as scientific research can access objects and related information without unnecessary movements and handling, which can prevent injuries. Mass storage systems can be revolutionised this way and optimal conditions of storage can be introduced in the collections independent of acquisition sequence.

Hypertext CD and multimedia publications

Hypertext applications can be a new chapter in museum publication. This type of structured textual information can be familiar to all who use e.g., Windows and its help files. The novelty in the application of hypertext is in the new way of organising information. While the structure of traditional books is linear, i.e., following a straight logical or chronological order determined in the Contents, hypertext applications leave an immediate possibility to 'jump' between logically related units, not only text but images and audio files as well.

Contextual restoration of injured visual information

Some photos, either negative or positive, get into the museum collections in deteriorated state or suffer damages in spite of museum treatment. Formerly these objects could be restored only by sophisticated means of conservation. The conservation of the image, i.e., visual information received new potentials by the application of restoration of the content by image manipulation software packages. For example, a broken glass negative with collodium could be inserted only between two plates of glass, and a new positive was made where the break line could be retouched manually. This long process required also considerable skill. By modern means of image manipulation, the above mentioned problems can be easily solved. After registering the original state, faults can be corrected easily and the corrected image can be stored in electronic and photographic format as well on slide or Polaroid negative.

The development of modern technology including computer applications can enchant laypersons. At the same time as all wonders, it lasts but a few days. These means and media become part of our everyday routine, a handy means in museum work. Applied with due caution and not for their own sake, digital means of image processing can help in preserving contents and media of our cherished pieces of photographic information as well as presenting them for the wide public.

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Pictures of an Exhibition

Katalin T. Biró
Hungarian National Museum, Dept. of Information

The exhibition 'Prehistoric industrial district in the Bakony Mts.' was opened in the Laczkó Dezső Museum, Veszprém on the 15th of March, 1995. This exhibition gives an account of a joint research work which lasted for more than ten years, in collaboration with Judit Regenye. An interactive computer demonstration program is installed in the exhibition. This program gives additional information for visitors on the general theme. At the same time, this form of presentation may attract new audience to the museum as well as prehistory for whom traditional exhibition technique is not interesting enough. The exhibition program was published in CD form as well. The exhibition 'Prehistoric industrial district in the Bakony Mts.' presents the results of the excavation on and around the Tűzköveshegy (Flintstone Mountain) at Szentgál. The exhibition deals with several aspects of flint mining, including geological infromation on the formation of flint, material of the prehistoric quarry and related settlements, results of lithic analyses and the data on the historical utilisation of flint. There are realistic models indicating the contemporary environment. Detailed explanations and scientific information is basically provided by the interactive computer demonstration program. The 'computer exhibition guide' was made using public domain and shareware programs. The final format is a hypertext program called HYPLUS which was used in several other applications as well. The hypertext program met most of our basic needs: it is simple to use (only the cursor keys, or, alternatively, ENTER and ESC keys are enough to manipulate the program. Existing experiences made the editing work a simple technical task. The bulk of the efforts were devoted to the construction of illustrations. The present paper will concentrate on the technical and methodological experiences obtained during the preparation of the pictures of the exhibition.

I. Introduction

The exhibition 'Industrial District in the Bakony Mountains' was opened on the 15th of March, 1995. The exhibition covers more than a decade of joint research work on behalf of the Hungarian National Museum and the Veszprém county museum (Laczkó Dezső Museum). The excavations serving as a basis of this presentation were performed by the author and Judit Regenye, respectively. After more than a decade of joint and interrelated work, we decided to share experiences of research with the widest possible public, in the form of an exhibition, which will be open till the end of this year. An interactive computer guide is part of the exhibition, the first of its kind in Hungary. The computer exhibition guide offers additional information for visitors completing the general exhibits, models and reconstructions. It is hoped that this way of presentation can attract further layers of museum visitors for whom the traditional means of exhibition are not adequate. The new generation is being raised in a world of almost unlimited possibilities of visual culture. This 'computer picture guidebook' is primarily designed for them.

II. About the exhibition

The exhibition 'Industrial District in the Bakony Mountains' is dedicated to prehistoric flint mining and related problems. The origin of silex, preferred raw material of prehistoric people is presented with evidences of regional geology of the flint bearing layers and theri environs. Results of the excavations of the mine and workshop areas, lithic technology, related artisan settlements and transport of the material to distant archaeological localities are presented. Lithic specialists' studies, modern (historical and ethnographic) utilisation of flint is also presented. Realistic models, large photos try to give an impression of the former environment of the mine and related settlements. A detailed explanation of the underlining historical processes is mediated through the computer guide.

III. Software basis

We have been playing with the idea of an interactive computer demonstration program in an exhibition for a long time (Biró, Múltunk jövője '93, see this volume). Expectations concerning the program were the following:

It had to be simple to handle, and 'fool-proof'. We could not afford to use sophisticated solutions and had to think about installing the simplest, minimal hardware.

Also, the contents had to be clear and simple. At the same time, we had high notions on the quality of information. Due to the pioneering character of our enterprise in Hungary and the lack of funds, we were looking for a program in the frames of which the construction of text and images as well as completions could be performed on our own. The solution could be found within the growing field of public doimain and shareware programs. The basis of our exhibition guide is a DOS based hypertext program, HYPLUS by Neil Larssen. The 'motor' of the program was taken from the first Hungarian electronical textbook on the use of long distance networking facilities (Drótos et al. 1994). This program was used with considerable success for creating our own electronical textbooks (Rajczy-Munkácsy-Biró 1994). The program could be used not only as textbook, but also as a means for presentation in a lecture on the subject (Rajczy-Munkácsy-Biró 1994a). During 1994, several presentations were made in the same system by the help of a projector screen .

The hypertext program met most of our requirements. It is very simple to use; the program can be operated using the four cursor keys alone, or, as an alternative possibility, using ENTER and ESC. The existing experiences on construction of hypertext systems were enough for the construction of the text and the logical ordering of the information. At the same time, the presentation of visual information, i.e., pictures, was a real demanding task. The construction of the exhibition guide certainly reached the limits of the program applied. This paper is consecrated to the specific problems encountered during the preparation of the illustration material.

Before dealing with the problems concerning the images, let us quickly summarise the potentials of the hypertext program. Hypertext, as such is nothing else but a structured text in which we can make 'jumps' and define 'links', between semantically related parts of the text. Jumps in this program (HYPLUS) mean the invitation of other files or programs within the frames of the text. The formal criteria of a jump in HYPLUS is symply to use frame codes . The string within the frame codes is interpreted as a file name which is invited or performed, after which the reader/user can return to the starting point or make other jumps. Hypertext applications currently have great potentials in WAN applications and a graphical environment like the World Wide Web. The version of HYPLUS used for the exhibition guidebook offered more modest possibilities is a puritan DOS environment.

The main advantage of the use of hypertext systems were very concisely summarised by the developer of the program, Neil Larson:'

Building hypertext systems (semantic taxonomies to show conceptual dependencies) creates subject mastery unmatched by other intellectual processes. Those who create hypertext understand the subject better than anyone else.'

Hypertext systems can be used, apart from the discovery of the underlying semantic relations within the subject, to invite pictures, images, programs and their integration to the text, thus they can 'carry' full multimedia presentations as well. The Szentgál exhibition guide, however, did not aim at integrating sound effects, the conveyed information was restricted to text and images.

IV. The origins of the pictures used for the exhibition guide

The text compiled and structured according to the specific subject had to be completed with abundant illustrative materials, images for the benefit of the visitors. The illustrative material dealt with, partly, the Szentgál-Tűzköveshegy mine and workshop area and partly to the general explanations on the subject. An essential part of illustrations of former scientific papers on the subject were integrated. Thus some images of the slide-show compiled for the conference 'Future of our Past '93' (see this volume) were included as well as 3D model of the excavation area constructed for the GIS conference in Ravello 1994 (BIRÓ–FEJES 1995) or elements of raw material distribution series (BIRO 1991). Naturally, the available set of illustration material was not sufficient to cover all aspects of the exhibition, therefore a large amount of new images had to be installed. By the time of the opening of the exhibition, some 200 images of 30 Mbyte disk space supported the computer exhibition guide. Later on some 'neglected' areas received further images like the section of geology or the excavation of the settlement sites around the Tűzköveshegy. The complete set of illustrations were extended to 32 Mbytes. Further steps concerning the guidebook included a three-day presentation during the 1995 CAA meeting in Leiden, which was a very intensive testing with lots of practical experiences and the publication of the first museum CD in Hungary.

V. Technical problems concerning the illustration material

From a mere technical point of view, the production of of the illustration material was a versatile and demanding task. A major part of the illustrations were actually made in, even, by the computer. The images on the monitor were saved in presentable form by the relevant software, if the program allowed. A large part of the computer generated images on the screen had to be saved by different screen capture programs. Text files were saved as images by prtfile. Graphs in a DOS environment were captured by camera of DeLux Paint. Images generated in Windows environment were saved, if not by their original facilities, using the clipboard and different graphical programs, from the simplest Paintbrush till highly sophisticated Adobe Photosop. Quite often, conversion between platforms (IBM compatible machines with MS-DOS and Macintosh system) was necessary. The images were saved in pcx format which is conveniently readable by the hypertext program.

Another part of the illustration material originated from 'outside' the computer, like photos, black and white drawings, original photographic images and micrographs. They were 'fed in' the computer by the help of a different intelligent periferias. I have to express my thanks to a number of colleagues who allowed me to use facilities in their ppossession. First of all, the Archaeological Technical Centre of the National Science Foundation installed in the Archaeological Institute of the HAS (Macintosh image analysing system, microscopic and video digitalisation, scanning), and the Photographic Collection of the National Pedagogical Library and Museum (scanning) as well as Ákos Burkus of the Museum of Fine Arts, for the use of digital photocamera. By the help of these equipments and relates software, demanding tasks could be solved like the preparation of a readable version of a 18th century chart from a small noisy facsimile copy or the colouring of isoscale maps.

Thus the 'pictures of an exhibition' could be presented not only within the computer but among the exhibits as well.

Transformation, conversion of the original pictures was often necessary, due to limitations of the hypertext program, hardware conditions (base memory, video card) and colour differences and image size. These transformations could be made partly within the graphical programs used, partly by special programs designed for image transformation (e.g., Graphic Workshop).

VI. Slide-show

An especially valuable and informative part of the illustration were the two slide-shows, giving an insight into lithic technology and related studies (knapping, refitting). The material used for the demonstration was experimental evidence by G. Brown from the Lithotheca collection of the Hungarian National Museum made on Szentgál radiolarite. Gary Brown visited the site in 1986. Being an experienced knapper, he produced cores, blades and tools from local radiolarite by the help of quartzite hammerstones. The original block could be reconstructed from the waste and flakes. The slide-shows in the exhibition guide present this process in two series interrelated but of opposite direction. Refitting and 'flaking' were recorded step by step by the help of a digital camera (photos by K. Takács). The individual steps arranged to short slide-shows were invited from the hypertext by individual DOS commands. The base commands were embedded in vpic, another shareware program for graphical presentations. Later, the facility of inviting DOS commands from the hypertext was used for the more complex images (typically, photos in resolution of 640*480 pixels and 256 colours). These images were too large for the viewer of the hypertext program and could not be presented in acceptable quality in pcx format. After good experiences with the slide show, these pictures were transformed into self-executive 'program' form (exe format), and they could be included in reasonably good quality.

VII. After-life

The material of the exhibition guide was planted to its destination in several steps. First, a limited version with the basic concept, a few pictures and the program itself (HYPLUS) were introduced to colleagues in the Veszpr,m museum with whom we were working on the exhibition. After discussing potentials of the program, the full text had to be written up (conjointly), as well as additional information was gathered. The first fully operating and cross-referenced hypertext version (1.0 version) was installed on the presentation computer one week before the opening of the exhibition.

In this form, the program was tested by the Veszprém museum staff as well as colleagues in Budapest. We had to make several modification, concerning, in the first place, the slide shows and the more demanding images. Also, the translation of the German text had to be completed. The 1.1 version (the state of the exhibition guide on the opening of the exhibition) is preserved on a data-CD and full text printed for documentation purposes. The same text (without illustrations) is included in MEK (Hungarian Electronic Library).

The 1.1 version was later completed with further illustration material, and underwent intensive testing in exhibition use and conference presentation. An important lesson for us during this testing processes was the necessity of literally translating images. Thus most of the figures, at least the ones with inscriptions, are now in three versions, with Hungarian, English and German captions, respectively. The final version was published on a compact disk, the first museum-CD in Hungary.

Both the exhibition guide and the CD had a positive response, from a professional point of view. The periodical ABCD made a second edition of the 'monograph', in a more attractive graphical environment but without the language variants and the slide shows. At the same time, the reception of the CD as a way of publication is not so fortunate - partly, because of the novelty of this type of publication.

References

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Archaeobotanical and Holocene palynological database

Zsófia Medzihradszky
Hungarian Natural-History Museum, Botanical Department

This database was constructed with an aim to collect vegetation historical evidence relative to the Holocene period from the scattered information published in Hungarian archaeological, archeobotanical, palynological literature. By this, we hope to support the work of environmental archaeology and scientists who want to use these data in their studies. We are planning to translate the database into English and provide information through the long distance network.

Structure of the database

The system is currently developed in DataEase RDBM system. We are planning to serve data as part of the multidisciplinary databases of the Archeocomp Association on X.25 and the INTERNET.

Current data sheets:

1. Literature, containing bibliographical data on the publications elaborated
2. Coenology, containing the floristical and vegetational indications of the plants included
3. Catalogue, this is the core of information containing site, plant, quantities, preservation, age, publication as well as comments

Current contents of the database:

1. To my best knowledge, all published archeobotanical references relevant to Hungary. Please, check the list!
2. All of the anthracotomical data relative to archaeological sites
3. Palynological data relative to archaeological sites and periods in a depth corresponding to the original publication.

The database is made using the financial support of the T6425 OTKA grant. We are trying to make the database directly useful for research workers, therefore all remarks, comments are heartly welcome.

The "BASE" Graphical Artifact Inventory and the "THEO" Terminology Classification Systems

Suhajda Attila
Hungarian National Museum, Dept. of Information
1370 Budapest, Múzeum krt. 14–16.
Tel.: 138-2122/48
E-mail.: H4763SUH@ELLA.HU

About the Task

Our main task was to create a comprehensive artefact inventory system for storing necessary details, images and detailed drawings of the museum's collections. This would mean the entering into computer format the details of the approximately 1 400 000 objects in the Hungarian National Museum's collection, as well as the recording of 2-300 000 photographs within a realistic time-frame and the making available of the resultant data bases for research and educational purposes.

The task was divided into two stages (levels). In the first stage we intended to explore the base-system, which would not contain significantly greater information than that contained in the general artifacts-register. In total, 16 pieces of information are contained on each object (Figure 2.) capable of serving the different types of collections (e.g. archaeological, medallion, furniture, painting, etc). The second stage would see the development of the so-called researchers' databases, which are collection-specific, their basic structure varies and they include all the information on any given object. Permission for their use can only be granted by the director of the collection in question. The common link between the two data-base levels is represented by the fields of the basic data-base. (Figure 1.)

The "BASE" database

The aim of the "BASE" is to guarantee a uniform data structure for the archival of information on the various collections. The "BASE" contains relatively few (Fig. 3.) information on each individual artefact, although it is capable of storing data on every artefact, independent of artefact-type. This system contains 9 larger and 7 smaller secondary databases. Pictures are also included amongst the stored data. The system was so designed as to be able to convert databases prepared by other museums in programmes such as DataEase, for example. The system is compatible with DataEase for Windows, thus allowing those users with a PC and a network connection access to the system. an interesting element of the system is the Age/Period database (Fig. 2.), which is capable of visual representation of the chronological table. It also allows the possibility to select artefacts (with the mouse) from a particular section of time (a given period, culture, concrete date, time-interval, etc.).

In the above table, the inventory number, place of collection and the dimension records may incorporate two or more information fields. The data entry form of the object see below. (Fig.4)

The "BASE" includes 9 secondary databases in total, of which the 6 listed below are also independently useful:

1. Glossary of Place-names (including variations in names)
2. List of Countries
3. List of Institutions
4. List of Collections
5. Period/Age Glossary (Chronological Table)
6. List of Materials

In part these secondary lists exist DataEase format1, and they only require to be converted to the INGRES system.

At present the number of DataEase records suitable for transferral into the base-system numbers approx. 150.000. This number represents the entire Roman, 15% of the stone-age, as well as a number of smaller collections (such as the Palaeolithic). The approx. 40.000 records comprising the Roman collection have now been converted to the new system.

Classification and Naming of Artefacts

The greatest problem was the handling of the varying names given to particular artefacts. This lack of uniformity is especially true of the archaeological artefacts. It is not difficult to imagine the difficulty of searching for objects in such non-uniform databases. It was very clear to us that we cannot wait for the development of a uniform naming system - especially considering that Flóris Rómer becried the lack of such last century. For this reason we set about developing a means for handling this problem.

The *"THEO"* term-classifying system

One of the singularly most important elements of the HNM database is the thesaurus program. The ***"THEO"*** program stores the various artefact names, classifies them and attempts to replace the dictionary of archaeological terms. With its assistance we can search for those types which are identical, but called under different names. Uniquely, this thesaurus database is able to visually represent the different groups, titles and related artefact-types also.

Every title comprises a so-called "carton", which includes the picture of the artifact-type, description, synonyms, etc. It is an important advantage of the system that through its use a uniform Dictionary of Terminology can automatically come into being.

*The **"THEO"** uses 3 types of descriptors:*

1. Main decsriptor - naming of artefact-group or artefact type.
2. non-descriptor - synonyms of the main-descriptor
3. part-descriptor: - definition of a part of an artefact: eg. visor of a helmet.

Each descriptor comprises a "descriptive carton", containing the following information:

1. Name
2. description- description of the artifact-type
2. synonyms
3. related concepts - certain main-descriptors according to various viewpoints.
4. picture- small explanatory figure of the given type

"THEO" allows the use of synonyms for a given artefact type, whilst guaranteeing that the artefact can be retrieved. It allows the possibility for the retrieval of a group of artefacts, as well as the joint seeking of related artefact-types.

It is important that the program is written in graphic format, and that the classification and relationship between categories can be visualised.

About the Program

We have yet to mention the hardware with which the system was developed. The central computer is a SUN SparcServer 10 operating under UNIX. This machine serves all those units connected to it. The system was developed with the assistance of the 4th. generation database handler, the INGRES version 6.4. The program functions on SUN work-stations, graphic X-terminals and traditional PC machines.

For those already familiar with the DataEase environment, we will prepare a variant which, with the exception of the *"THEO"* and the chronological tables, will operate with almost all of the important functions.

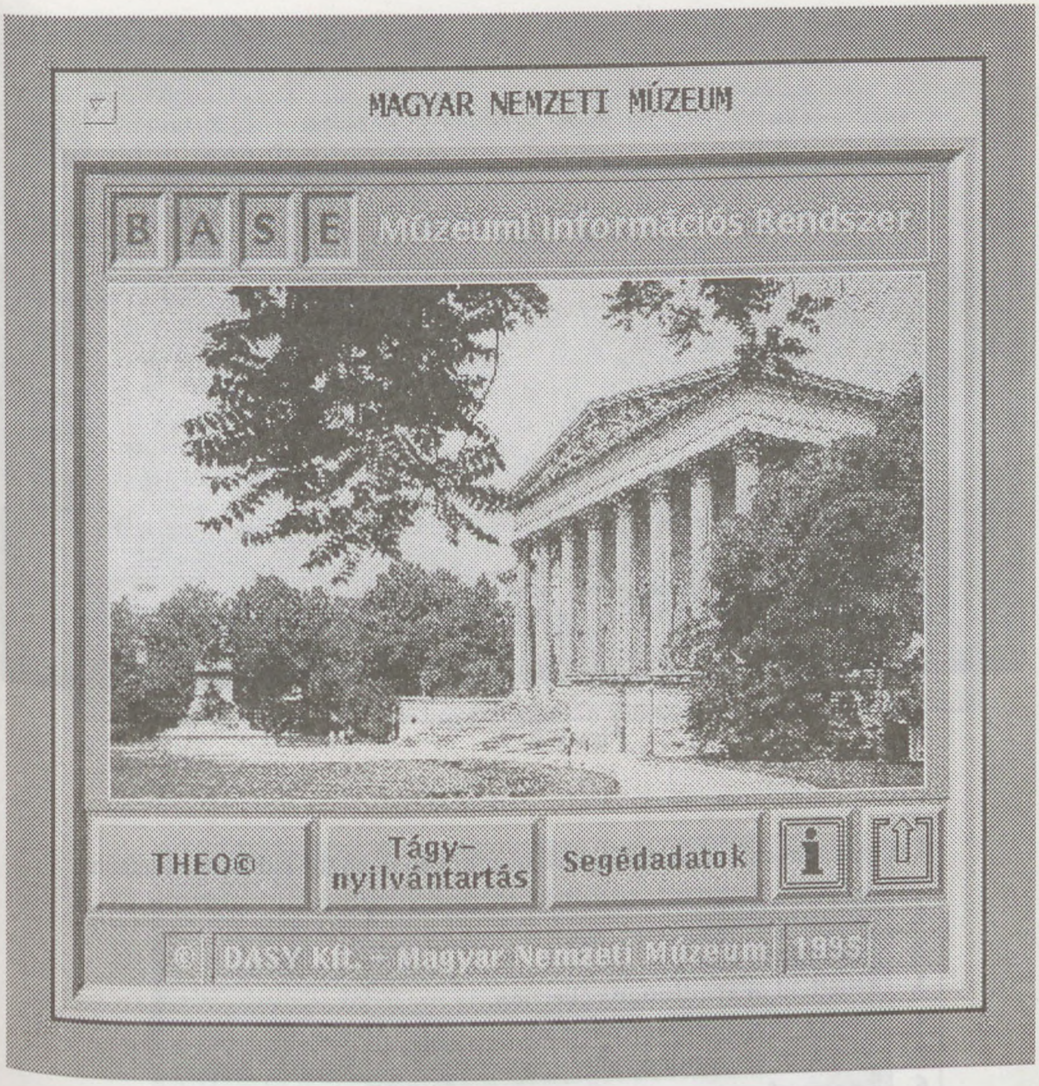
Without submerging ourselves in technical details, it is important to mention the adaptability of the Ingres system and the satisfying results it achieved. This is the first Museum archival system in Hungary to work with the UNIX system. It must be said that this system is very capable of storing great amounts of information. With the Ingres system, we were able to solve tasks previously unhandleable with PC machines. As we are speaking about a system operating within a sizeable network environment, the secure availability of the databases becomes a real possibility.

On Image Storage

In previous years we have already experimented with image storage, although the results were not too spectacular, due to a lack of the appropriate hardware and storage capacity. Last year we succeeded in developing an image storage work-station, comprising a Screen Machine video-signal digitiser card + a Hi8 SONY video camera, a fast Fujitsu mono scanner and a quick but high-resolution colour ESCOM scanner. Up until now approx. 4500 colour 640x512 resolution 16.8 million colour pictures have been stored using the video-camera.

In conclusion

We have outlined the results of the work in progress at the HNM in the hope that the setting to work of the system will perhaps also set the case of museum archival systems into motion. We believe that a recommendation may perhaps be forthcoming from the Ministry which could provide the basis for a uniform archival system according to the points outlined at the beginning of this article. It should not be necessary to await the new Museums Act to implement this. Should none of this occur, then we can still say that we have an archival system guaranteeing research, which can serve as the basis for a uniform national artefacts' database.


MAGYAR NEMZETI MÚZEUM
B A S E Múzeumi Információs Rendszer
THEO©
Tágy-nyilvántartás
Segédadatok
© DASY Kft. - Magyar Nemzeti Múzeum 1995

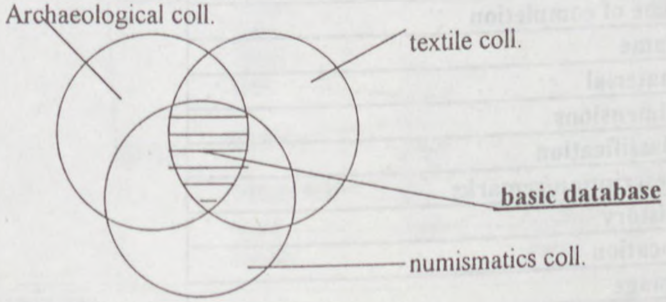

Archaeological coll.
textile coll.
basic database
numismatics coll.

Figure 1.

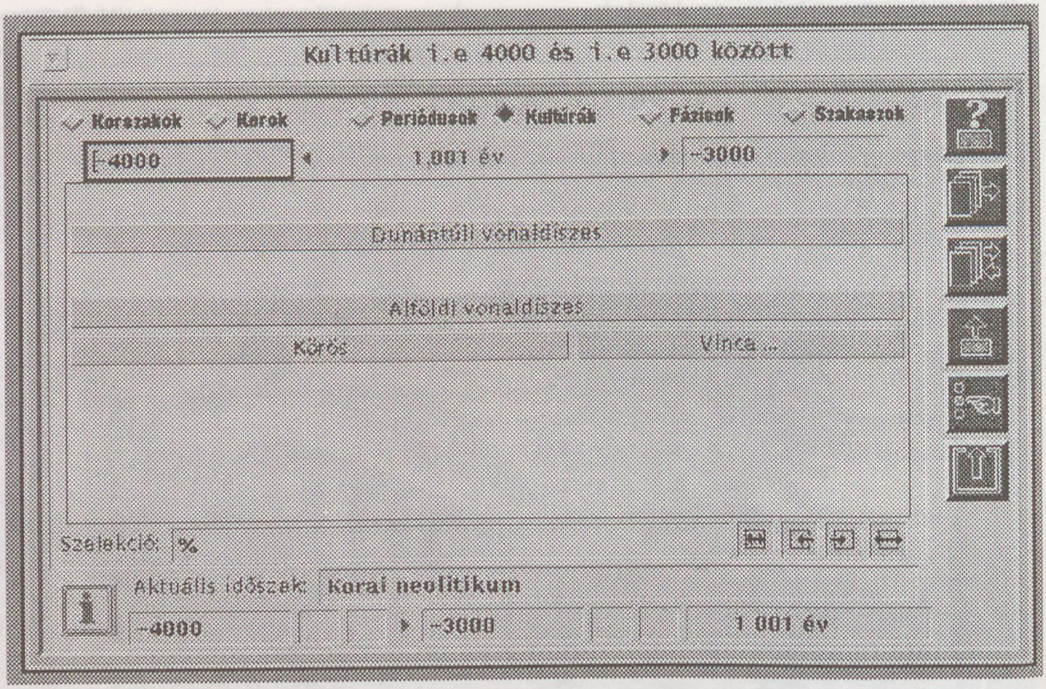
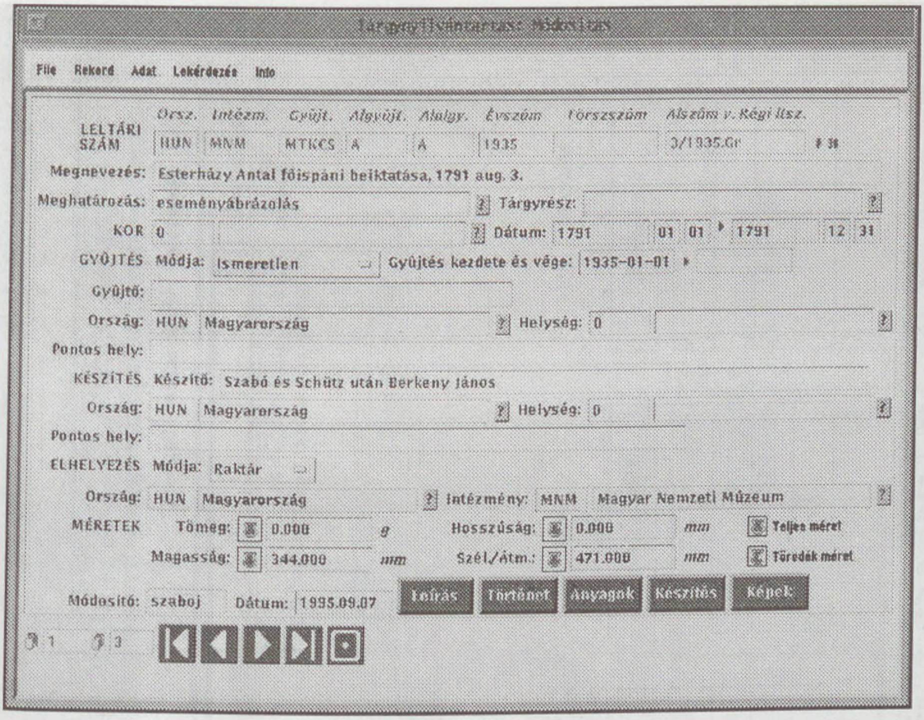


Figure 2.

The base system includes the following information on the individual artefacts:

1.	**inventory no.**
2.	**collector's name**
3.	**method of acquisition/collection.**
4.	**place of acquisition/collection**
5.	**time of acquisition/collection**
6.	**name of person completing these details**
7.	**place of completion**
8.	**time of completion**
9.	**name**
10.	**material**
11.	**dimensions**
12.	**classification**
13.	**description/remarks**
14.	**history**
15.	**location**
16.	**image**

Figure 3.


Tárgynyilvántartás: Módosítás
File Rekord Adat Lekérdezés Info
LELTÁRI SZÁM
Megnevezés: Esterházy Antal főispáni beiktatása, 1791 aug. 3.
Meghatározás: eseményábrázolás
Tárgyrész:
KOR
Dátum: 1791 01 01 1791 12 31
GYŰJTÉS Módja: ismeretlen
Gyűjtés kezdete és vége: 1935-01-01
Gyűjtő:
Ország: HUN Magyarország
Helység:
Pontos hely:
KÉSZÍTÉS Készítő: Szabó és Schütz után Berkeny János
ELHELYEZÉS Módja: Raktár
Intézmény: MNM Magyar Nemzeti Múzeum
MÉRETEK Tömeg: 0.000 g
Hosszúság: 0.000 mm
Teljes méret
Magasság: 344.000 mm
Szél./Átm.: 471.000 mm
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Dátum: 1995.09.07
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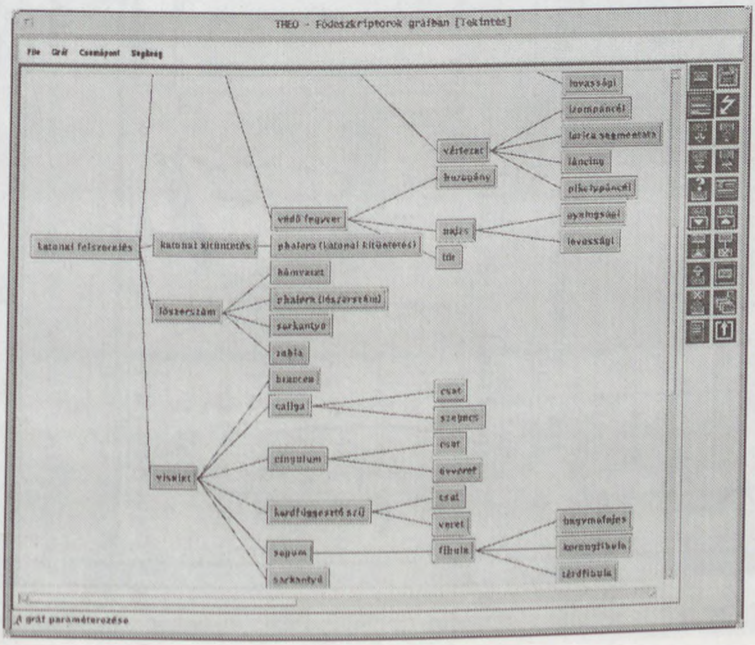
Történet
Anyagok
Készítés
Képek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lovassági
lánding
hámvezet
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cingulum
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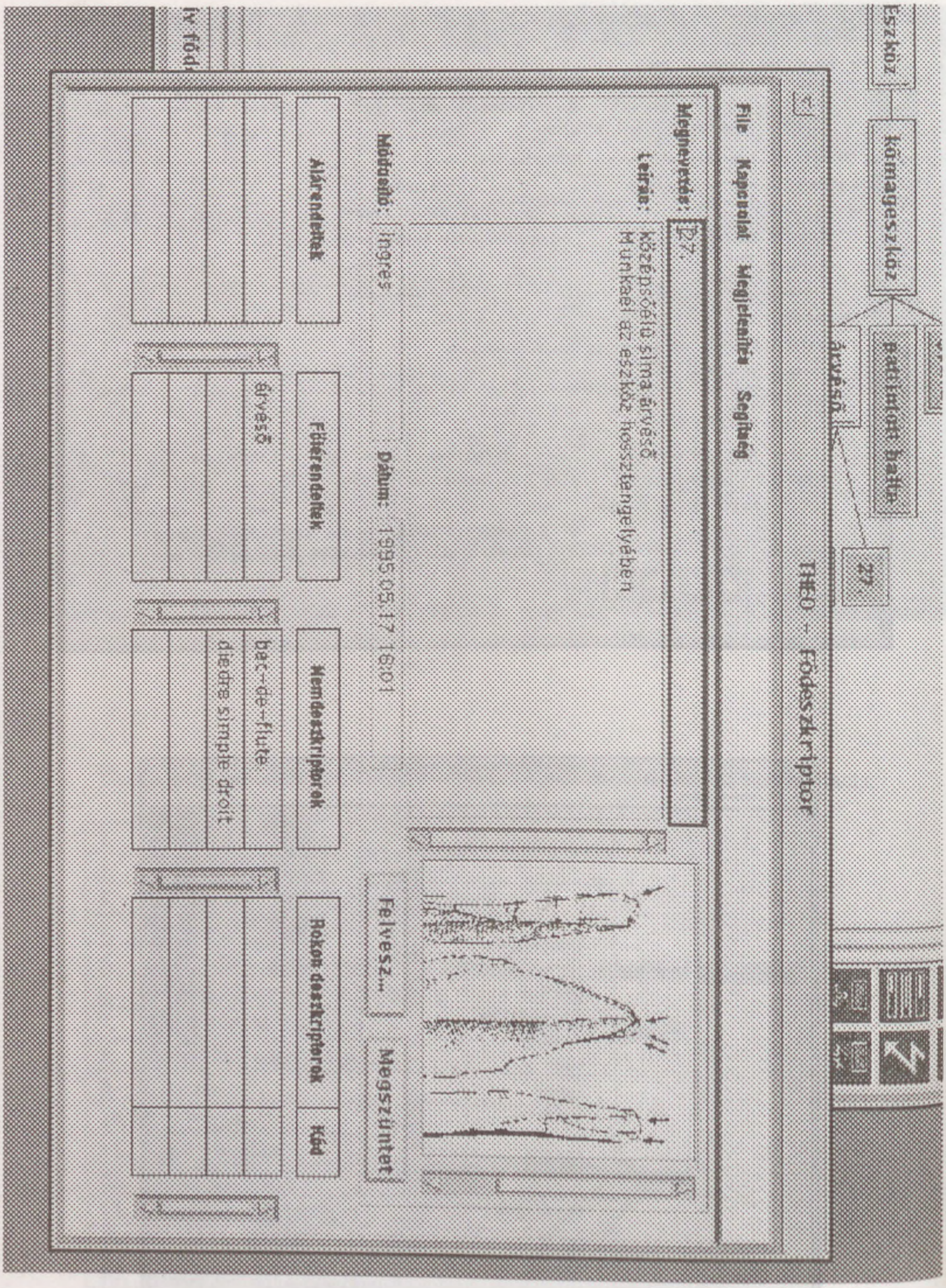
csat
fibula
A gráf paraméterezése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Munkaél az eszköz hossztengelyében
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Dátum: 1995.05.17 18:01
Alárendeltek
Fölérendeltek
árvéső
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bec-de-flute
diedre simple droit
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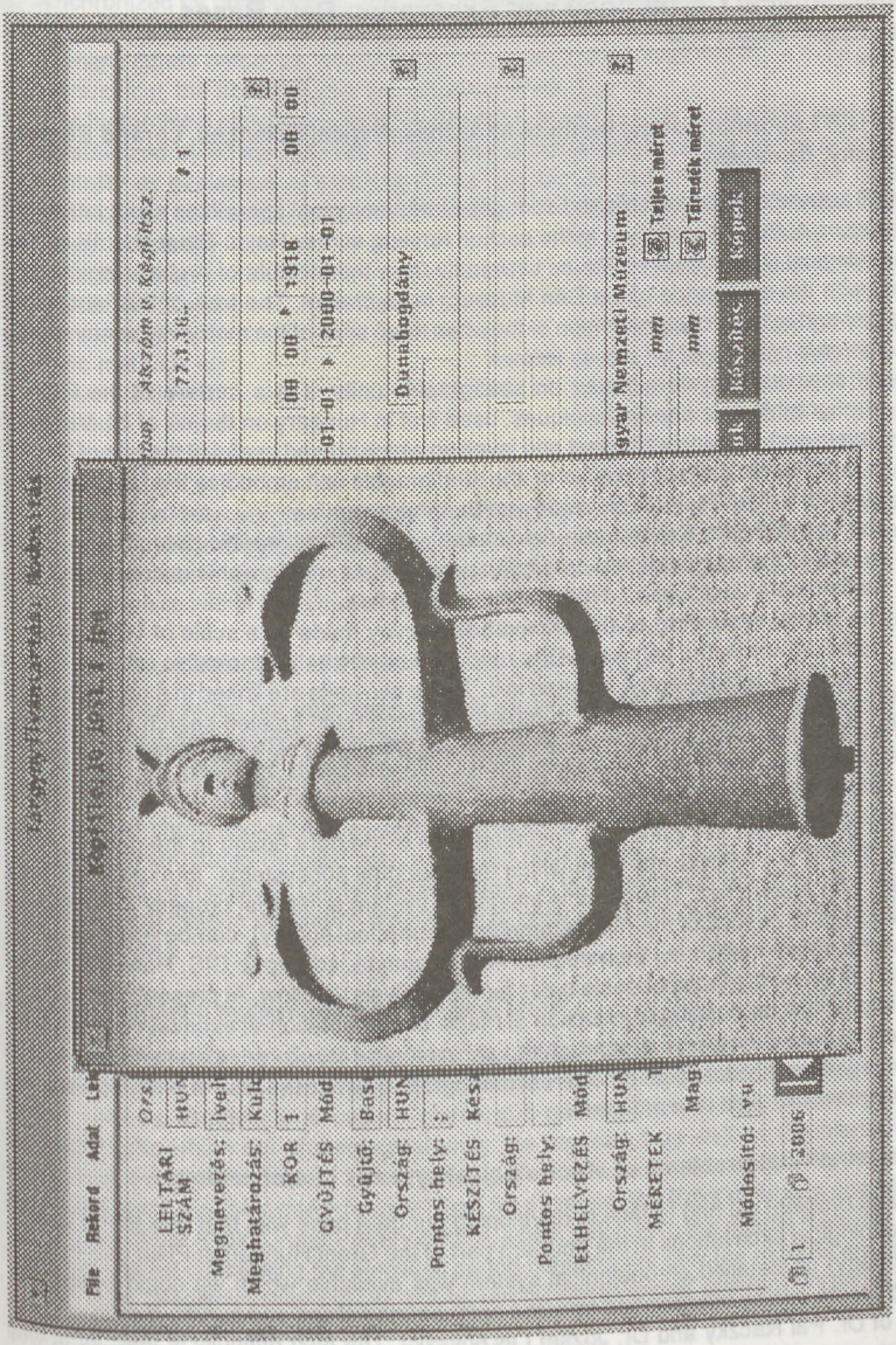
Kód
Felvesz...
Megszüntet
Eszköz
pattintott balta
árvéső
27.

(Figure 7.)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Rekord
Adat
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KOR
GYŰJTÉS
Gyűjtő:
Ország:
Pontos hely:
KÉSZÍTÉS
ELHELYEZÉS
MÉRETEK
Módosító:
Dunabogdány
gyar Nemzeti Múzeum
Teljes méret
Töredék méret

(Figure 8.)

Archaeological Chronology and Excavation Data Bases

Zoltán Czajlik–Balázs Holl

1. The GIS Laboratory of the Institute of Archaeological Sciences, Loránd Eötvös University, Budapest

The GIS Laboratory was established during the archaeological operations associated with construction of the M3 motorway in the section running across Hajdú-Bihar county, by the Archaeological Department of Eötvös University (now the Institute of Archaeological Sciences) with the assistance of the Déri Museum in Debrecen. The task of this laboratory is the fast and reliable documentation of the often huge sites of the motorway excavations.

The elements of this system are as follows:

- an excavation system based on stratigraphic units: it is a mixture of the French stratigraphic data sheet techniques, used first in Hungary on the hill of St. Vid near Velem and drawing with exact grid levelling which proved useful at the site of Polgár - Csőszhalom. In its present form, the stratigraphic unit embodies the basic archaeological unit while features represent the phenomena.
- **the computerized data base** developed from the stratigraphic data sheets. Each record in the computerized data base represents a stratigraphic unit and contains its field data (localisation, type, dating, comments).
- **the digital recording of the excavation survey** made on a scale of 1:20, with the detail drawings, the pathway of the road, and other truely informative map elements (e. g. relief, hydrography) inserted in it. These two units are linked in a computerized way through the stratigraphic numbers, ensuring multi-faceted search possibilities.
- a digital map system which serves in the presentation of the sites' wider environment and the identification of aerial photo positions. The scales chiefly employed are 1:100,000, 1:10,000 and 1:2,000.

The basis of our computerized documentation is the data bound to the geographical place. This is the interface through which the individual subsystems form an integrated system with each other. Through this integrated system additional properly analysed information (e. g. results of the magnetometric geophysical survey) can be encorporated.

All the above mentioned elements do not, of course, add up to GIS. However, in our opinion, they are the indispensable basis for the analysis to follow. At present, our primary task is practical processing (production of maps, documentation of excavations including general drawing, drawings separated into chronological levels, development of the data base as well as the identification of aerial photographs), while the task of analysis can only commence once field research ends.

2. The structural problems of chronological systems in archaeology

The first problem we had to face in developing our data base was that due to the lack of archaeological excavations in the northern part of the Great Hungarian Plain (environs of Hortobágy) no detailed chronological system was available which we could adapt. We could create one by interpolation from the neighbouring areas and survey results with the help of Dr. Pál Raczky and Dr. József Laszlovszky. The next difficulty is that, as is well known, many different chronological systems may be used at the same time. These must be synchronized by computer as much as possible, quite often in the absence of professional consensus.

As many others before us, we classified chronological systems into three main groups: the hierarchical, the absolute and the cultural system (Fig. 1).

The hierarchical structure is most traditional and perhaps the most static approach. It is characterized by all the features of the geological paradigm based on the principle of horizontality as explained by Nicolaus Steno, the Danish-born physician at the court of the Grand Duke of Tuscany in 1669. Although in practice archaeologists use this method only when absolutely necessary, it is easily adaptable for computer processing. While the structure based on absolute chronology similarly lends itself to easy computerization, the problem is that it is only very rarely available during the course of excavations. Never-the-less, this system should not be ignored since numerous "absolute" data are provided by scientific methods such as ^{14}C assessments and dendrochronology. Naturally, the cultural structure developed by archaeologists is the most complex since it attempts to follow change both in time and space. (Fig. 2 shows some theoretical possibilities for connections between archaeological cultures). It is not an easy task to adopt this typical archaeological system to the computer, especially if one considers the problems of synchronisation between chronological systems based on pottery styles. The special problem of transitional periods must also be mentioned here. In our case it was primarily of practical concern, since levels cannot always be precisely separated merely on the basis of ceramics within this structure.

3. The data base structure of archaeological periods

This sub-system within our data base was structured without the intention of solving the aforementioned archaeological/chronological problems, leaving them to the specialists. Our system was designed to accomodate modifications following the complete archaeological evaluation of the ceramic material and the acquisition of scientific dates. Our computerized chronological sub-system enables us to communicate freely between the chronological structures detailed above and the possibilities of crossing between structures can also be modified. The technical solution to this problem is the combined use of the hierarchical system of relative chronological units synchronized with slipped time intervals (Fig. 3-4).

4. The hierarchical system of chronological units

All expressions used in archaeological dating corresponds to a chronological unit in our data base. These are, as seen in Fig. 3, organized into 9 types (period, age, stage, transitional, century, absolute time, culture, phase, sub-phase). Thus, thanks to the hierarchical system into which the chronological units are organized as well as the hierarchies established even within pottery types, the questioning works automatically through the entire data base. So the system "knows" that, for example, the Bükk culture is one of the sub-phases of the Alföld Linear Pottery culture, which belongs to the middle Neolithic etc. Therefore the list concerning the Neolithic period contains not only the records assigned to Type 2 as "Neolithic" (see Fig. 3), but hierarchically arranged relevant chronological units from Types 3 to 9 as well.

5. Slipped chronological intervals

The system synchronizes chronological units not with fixed beginnings and ends, but using data from the archaeological literature in an slipped interval system. Thus, the opening of a chronological unit represents an interval between two dates and, similarly, the end of the same chronological unit is defined by an interval. (From the viewpoint of the system itself the accuracy of dates is irrelevant; Fig. 4).

The problem outlined here is, in fact, not a matter of computer application. It is much more a question of archaeological theory and method. Therefore we would like to emphasize that this system should be distributed both geographically and archaeologically as fast as possible. This expansion has neither theoretical nor practical limits. In deciding problems of synchronisation all comments and suggestions by colleagues are welcome. With this help we hope that, in addition to the digital maps already existing and under development elements of a genuine archaeological GIS will be created and a computerised chronological structure of the entire Carpathian Basin synthesized.

Acknowledgements

This project has been supported by *OTKA* Grant No. F6968 of the National Reseaerch Foundation and by the Soros Foundation. The English text was revised by Dr. Alice M. Choyke.

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Kemenczei, T.: *Die Spätbronzezeit Nordostungarns*. Akadémiai Kiadó, Budapest 1984.

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Raczky, P. (ed.): *The Late Neolithic of the Tisza Region*. Budapest–Szolnok 1987.

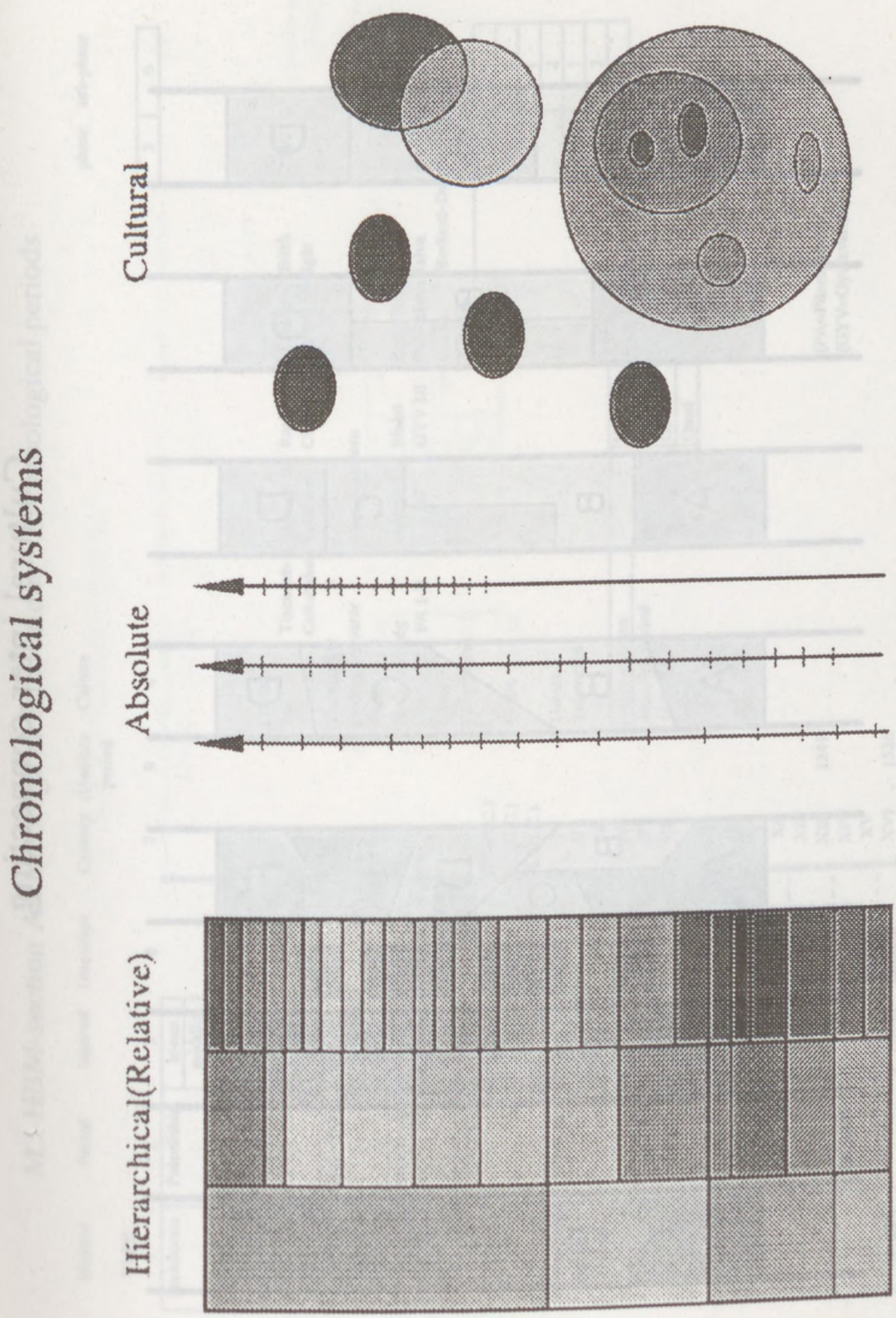
Chronological systems
Hierarchical(Relative)
Absolute
Cultural

Fig. 1

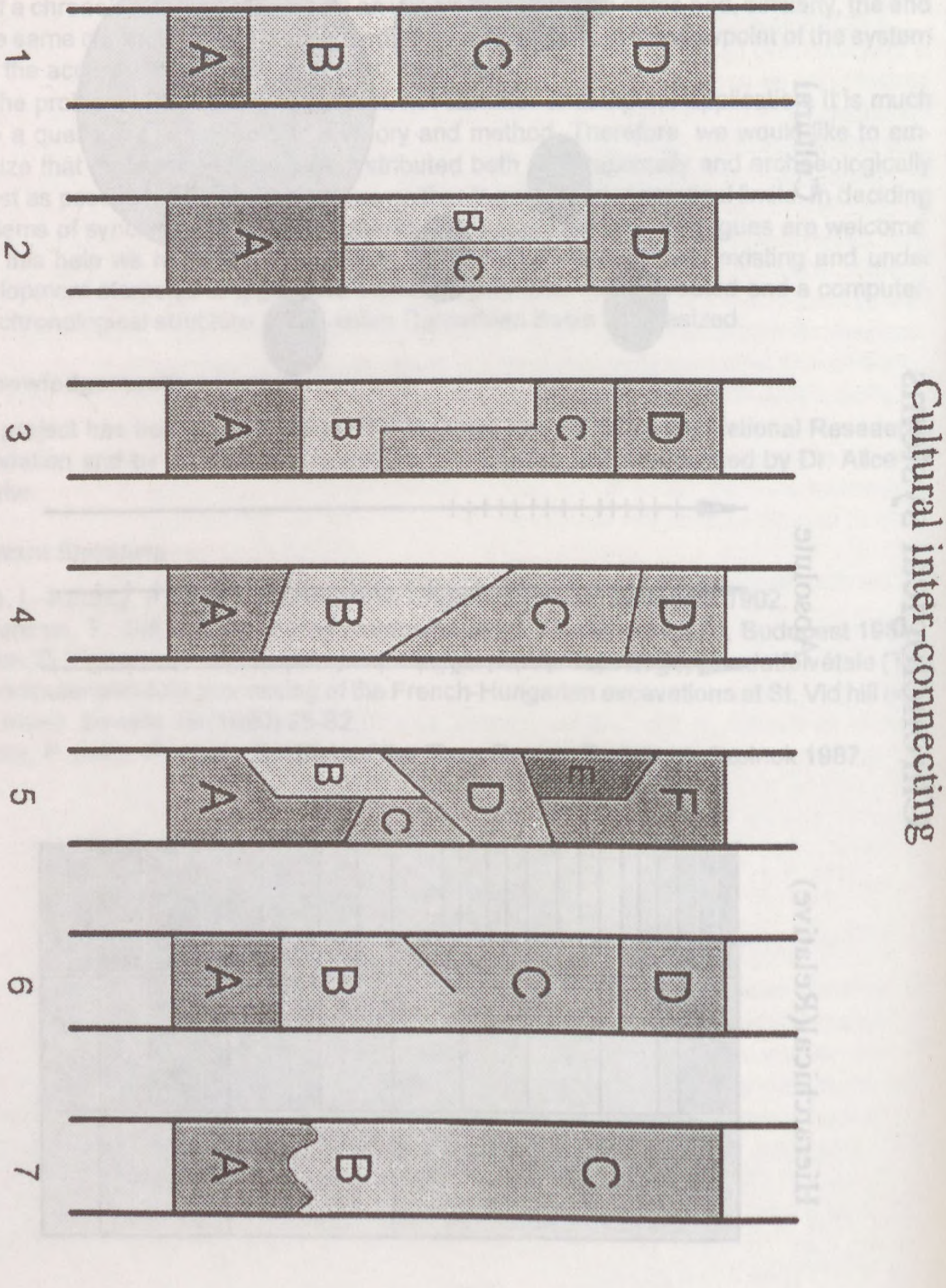
Cultural inter-connecting
1
A
B
C
D
2
A
B
C
D
3
A
B
C
D
4
A
B
C
D
5
A
B
C
D
E
F
6
A
B
C
D
7
A
B
C

Fig 2

M3-HBM-section Archaeological excavations - Archaeological periods

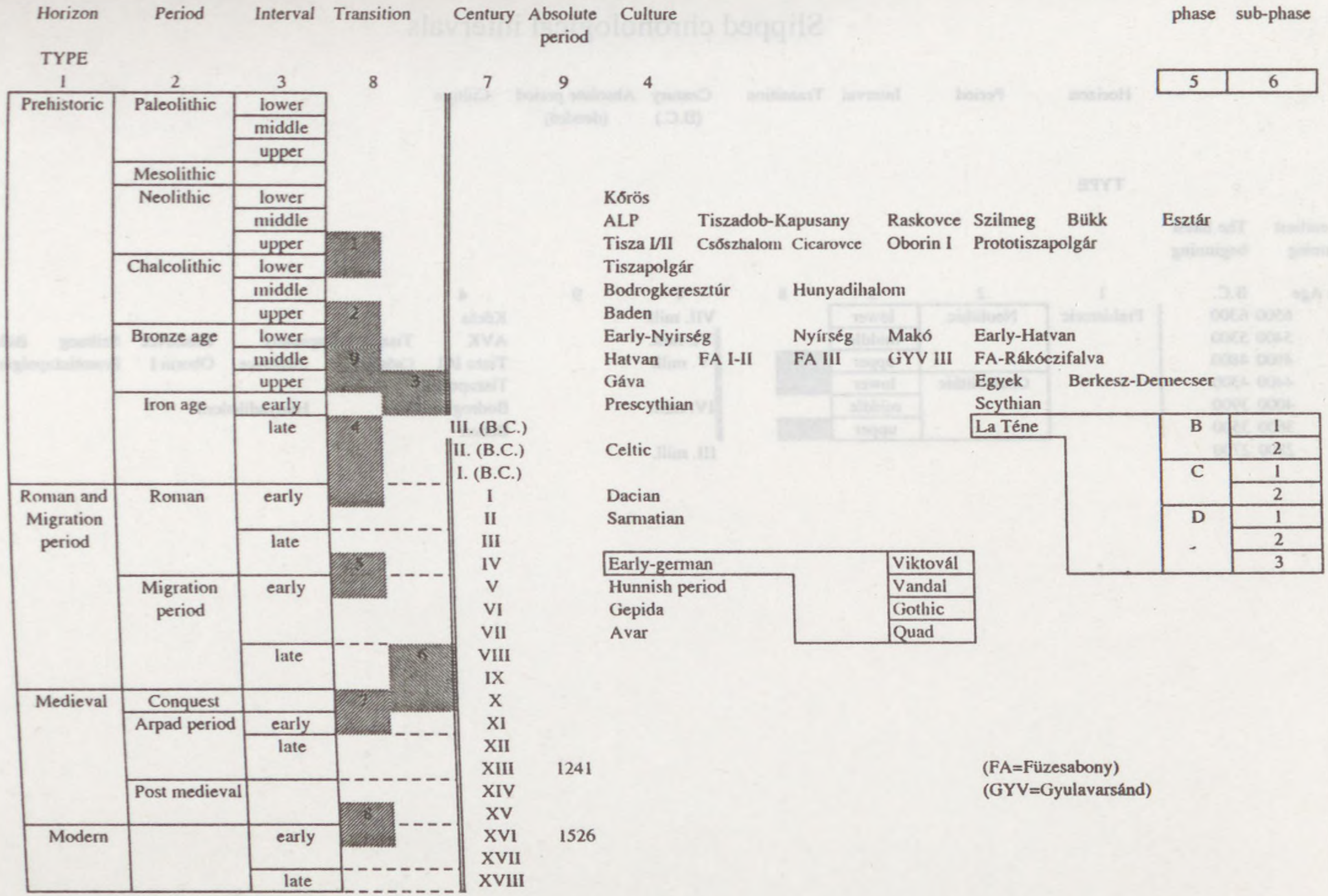

Fig. 3

Slipped chronological intervals

The earliest beginning	The latest beginning	Horizon	Period	Interval	Transition	Century (B.C.)	Absolute period (dendro)	Culture					
		TYPE											
True Age	B.C.	1	2	3	8	7	9	4					
6500	6300	Prehistoric	Neolithic	lower		VII. mill.		Kőrös					
5400	5300			middle		VI. mill.		AVK	Tiszadob-Kapusany		Raskovce	Szilmeg	Bükk	Esztár
4900	4800			upper	1	V. mill.		Tisza I/II	Csőszhalom	Cicarovce	Oborin I	Prototiszapolgár	
4400	4300		Chalcolithic	lower	1			Tiszapolgár					
4000	3900			middle		IV. mill.		Bodrogkeresztúr		Hunyadihalom			
3600	3500			upper	2			Baden					
2800	2700					III. mill.							

Fig. 4.