The Application of Geographic Information Systems to Archaeological Intra-Site Recording and Analysis: A Case Study of the Kissonerga Chalcolithic Site, Cyprus.

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Declaration

Let this be testimony that the contents of this thesis are based upon my own work and where the work of others is used this is duly accredited.

Abstract

The present thesis intends to offer a methodological approach to the application of Geographic Information Systems in Archaeology.

The aim is to focus this application on single site excavations and provide a fully integrated system which is capable of storing and processing the archaeological data from the beginning of the excavation to its final publication.

A comprehensive review of the history and development of the main GIS applications in archaeology is provided in chapter I.

Chapter II is a concise presentation of the site of Kissonerga, Cyprus where the system was implemented.

Chapter III includes an overview of the concepts around which the system was built as well as the system's levels of operation.

Chapter IV discusses the construction of the database structure which stores and manipulates the primary archaeological data.

Chapter V provides the methodology for the capture of the site plans in digital form.

The methods for analyzing the archaeological information with the aid of a GIS are presented in chapter VI. The main effort has been placed in linking the GIS with the database for the efficient exchange of information in an integrating fashion.

The ultimate aim of each excavation project is to publish the results of its activities. Therefore, chapter VII discusses a number of ways in which computer systems can assist to the task.

Finally, chapter VIII offers a critical appraisal of the system as well as some suggestions for its improvement in the future.

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VOLUME I

List of Abreviations

ACN : Archaeological Computing Newsletter

AIS : Archaeological Information System

ASCII : American Standard Code for Information Interchange

ASOR : American School of Oriental Research

B994 : Denotes building unit numbers

BANEA : British Association for Near Eastern Archaeologists

BAR : British Archaeological Reports

BASOR : Bulettin of the American School of Oriental Research

CAA : Computer Applications and Quantitative Methods in Archaeology

CD-ROM: Compact Disk Read Only Memory

CPU : Central Processing Unit

DBMS : Data Base Management System

DRAW : Direct Read After Write

DEM : Digital Elevation Model

DTM : Digital Terrain Model

EDM : Electronic Distance Measurer

ESRI : Environmental Studies Research Institute

GIS : Geographic Information Systems

Gr505 : Denotes grave unit numbers

IFA : Institute of Field Archaeologists

I/O : Input/Output

IT : Information Technology

IUSC : Inter University Software Committee

KAIS : Kissonerga Archaeological Information System

KM : Kissonerga-*Mosphilia* (referred to as Kissonerga only in all post 1989 publications)

KMyl : Kissonerga-*Mylouthkia*

LAP : Lemba Archaeological Project

LL : Lemba-*Lakkous*

NAR : National Archaeological Record

NARC : National Archaeological Record of Cyprus

NVAP : Nemea Valley Archaeological Project

RCHME : Royal Commission on the Historical Monuments of England

RDAC : Reports of the Department of Antiquities Cyprus

RDBMS : Relational Data Base Management System

SAM : Scheduled Ancient Monument

SIF : Standard Interchange Format

SIMA : Studies in Mediterranean Archaeology

SPSS : Statistical Package for the Social Sciences

SQL : Structured Query Language (standard)

TIN : Triangular Irregular Network

UTM : Universal Transverse Mercator (grid)

WORM : Write Once Read Many (times)

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CHAPTER I

Introduction

> "...the New Archaeologists to a large extent turned away from the approaches of history towards those of the sciences. ...[They demonstrated a] great willingness to employ more sophisticated quantitative techniques, where possible computer-aided, and to draw on ideas from other disciplines, notably geography" (Renfrew, C. and Bahn, P., 1991, p. 35).

It was not until the mid 70's that the concept of New Archaeology caused a revolution in traditional archaeological theory and practice. It strengthened the bond between archaeology and other sciences in an attempt to foster new approaches to the interpretation of archaeological evidence. At the same time the bulk of archaeological material was increasing to such an extent that it soon became evident that traditional manual methods would not suffice to manipulate the enormous amount of data that was being collected. Computer technology, in its various forms, offered an attractive possibility of more detailed and objective information processing as well as intra-site comparisons.

During the early 80's geography underwent its own revolution with the advent of Geographic Information Systems (GIS), which evolved in an effort to systematise the spatial recording and analysis of geographic entities. The capability with GIS of performing a variety of different kinds of spatial data manipulation and analysis offered a number of major potential benefits for archaeological research. In particular, the structural and operational complexity of GIS systems made them ideal for large scale applications where spatial referencing played a crucial role. As a result, both geography and archaeology embarked on the development of a number of ambitious projects of this type in the later 1980's.

1.1 Definition of GIS

The precise definition of GIS is still subject to much debate (Cowen, D.J., 1990; Savage, S.H., 1990) a fact that has led to much confusion and which has resulted to the erroneous classification of several CAD/CAM systems as GIS. Examples of such false assumptions are reflected through the definitions supplied by Clarke (1986) or Reilly (1991). Closer to a more objective definition of what GIS really are are the descriptions of Rhind (1981), Kvamme (1986), and Cowen (1988).

Rhind describes GIS as "those computer systems which have the capability to interrelate data sets pertaining to different variables and/or to different moments in time" (Rhind, D., 1981, in Savage, S.H., 1990, p. 23). Kvamme states that GIS are "systems that interrelate, manipulate, and analyze a variety of geographically distributed data in addition to mapping" (Kvamme, K.L., 1987, in Savage, S.H., 1990, p.23). Finally, Cowen gives his definition as "a decision support system involving the integration of spatially referenced data in a problem solving environment" (Cowen, D.J., 1988, in Savage, S.H., 1990, p. 23).

The more objective definitions of GIS are provided by Marble and Cowen. Marble sets four fundamental criteria on which the classification of a system as a GIS will be based. According to him a GIS should possess the following:

> 1. A data input subsystem which collects and/or processes spatial data derived from existing maps, remote sensors, etc.
>
> 2. A data storage and retrieval subsystem which organizes the spatial data in a form which permits it to be quickly retrieved by the user for subsequent analysis, as well as permitting rapid and accurate updates and corrections.
>
> 3. A data manipulation and analysis subsystem which performs a variety of tasks such as changing the form of the data through user-defined aggregation rules or producing estimates of parameters and constraints for various space-time optimization or simulation models.
>
> 4. A data reporting subsystem which is capable of displaying all or part of the original

> database as well as manipulated data and the output from spatial models in tabular or map form.
>
> (Marble, D.F., 1990a, p.10)

In addition to the above criteria, a fifth one has been added which states that a GIS should be able "to conduct spatial searches and overlays that actually generate new information" (Cowen, D.J., 1988).

What potential GIS has to offer to archaeology is first the collection storage and manipulation of spatially referenced archaeological data and second, the ability to conduct specialized studies (such as modelling, simulation, and spatial analysis) in which the spatial element plays a prominent role.

To provide a context for the subsequent discussion, several of the early GIS applications in archaeology will first be reviewed, as well as related application employing computer aided design/mapping systems (CAD/CAM), rather than GIS proper.

1.2 History and Development of GIS in Archaeology

In order to provide a comprehensive summary of the history and development of GIS in archaeology, it is necessary to refer to three relevant topics, namely the development of archaeological databanks (since a first "crude" definition of GIS is that they are "a number of specialized spatial routines laid over a standard relational database management system" (Goodchild, M.F., 1985, in Cowen, D.J., 1990, p.54), general GIS research areas in archaeology, and specific GIS applications.

1.2.1 Archaeological Databanks

The history of GIS applications in archaeology should be traced back to the early 70's when the first archaeological databanks started appearing almost simultaneously in the USA and the UK. These databanks were the result of intensive research work undertaken in the late 60's but for convenience, the major ones will be presented with reference to the year in which they were fully documented.

There are two distinct categories in which these databanks can be classified. The first is regional general survey databanks and the second, intra-site oriented databases.

1.2.1.1 Regional General Survey Databanks

In 1977, Limp and Cook came up with a general survey databank called ORACLE. By 1979 almost 4,000 archaeological sites had been registered on the system and four projects had made use of its facilities. These projects involved a cultural resource management inventory of prehistoric sites in the Ohio River floodplain in Indiana, an Archaic settlement pattern analysis, an assessment of the impact of an extensive survey in a small river drainage basin and finally, "an investigation of prehistoric area location choice and resource distribution in the Grandview-Rockport locality" (Limp, F.W. and Cook, T.G., 1981, p. 66).

Britain saw its first archaeological databanks emerging through the development of the first computerised SMRs (Scheduled Monument Records). Although SMRs were designed to handle local archaeological information as well as to record sites of national interest, continuous work has made them the most reliable and most frequently updated source of archaeological information in Britain (Lock, G.R. and Harris, T.M., 1991).

The Southwestern Anthropological Research Group (SARG) followed in 1978 with another general survey databank named after it. The novel aspects incorporated into SARG were the use of the Universal Transverse Mercator (UTM) coordinates to reference the registered sites, a significant degree of standardisation on the format of the data collected, and a primitive, but for the time revolutionary, method of encoding landform profiles to portray the typical landforms associated with the site in 3-D (see Plog, F., 1981; Gaines, S., 1984).

In 1980, the Arizona State Museum Site Survey Database (AZSITE) was produced. It incorporated eight main files consisting of the following subjects: (a) "inventory of and index to cataloged archaeological nonperishable collections", (b) "index to the Arizona State Museum library archives", (c) "inventory of and index to cataloged ethnographic collections", (d) "research file and index to the Arizona State Museum archaeological survey", (e) "inventory of and index to cataloged archaeological perishable collections", (f) "inventory of and index to photographic collections", (g) "inventory of and index to cataloged collections of prehistoric pottery vessels, and (h) "research file and index to catloged Southwestern ethnographic textile collections" (Rieger, A., 1981, p. 28).

A final example[1] of a major databank project was reported in 1981. It was called AMASDA (Automated Management of Archaeological Survey Data in Arkansas) and it contained three basic files: (a) A site inventory file, in which records were organised by site and included data items chosen for their value in a management research programme, (b) a land use file, which contained site data organised on a square kilometre basis, and (c) the project file, designed for organising "information about archaeological projects, those involving contracts as well as those funded locally or even unfunded, that have resulted in the location of sites or attempts to locate sites" (Scholtz, S.C. and Million, M.G., 1981, p. 17).

1.2.1.2 Intra-Site Oriented Databases

Sylvia Gaines presented ADAM (Archaeological Data Management) in 1971. It was a large database written in Extended Basic for the accommodation and analysis of ceramic information and other survey data from the Navajo Indian Reservation in northeastern Arizona. It was the first attempt to bring the computer to the field and it proved successful despite the fact that data had to be transferred to a mainframe computer via a modem over the telephone line (Gaines, 1981b).

The Koster Project, developed to accommodate the information deriving from the homonymous large and deeply stratified site in Illinois, was presented in 1976. The aims of this system were to improve archaeological data processing in order to resolve field stratigraphy, to organise the excavated material for specialised laboratory analysis and to enable the efficient sampling of flotation samples for each stratigraphic horizon excavated (Brown, J.A., Clayton, S., Wendt, T., Werner, B., 1981). It was another attempt to bring computers into the field but, in the same way as the ADAM system this was achieved only by maintaining a modem link with a mainframe.

The significance the development of the databanks lies in that they have paved the way by which archaeological information can be electronicaly captured, stored, and manipulated. The development of an archaeological database is also a fundamental requirement of the application of GIS in archaeology. Nevertheless, databanks did not suffice to treat the spatial dimension of cultures. The advent of GIS technology, however, provided the means and the methodology for the spatial treatment of archaeological data.

Having presented the development of databank applications we will now proceed in reviewing the proliferation of GIS technology in archaeology.

1.2.2 GIS and Archaeology

It was not until 1985 that the first papers on the suitability of GIS for handling archaeological data were published and a number of projects have since then emerged.

There are three distinctive lines of research involving GIS and archaeology: (1) Site location models for cultural resource management, (2) GIS procedure related studies[2], and (3) Studies addressing larger theoretical concerns related to landscape archaeology through GIS methods (Savage, S.H., 1990).

1.2.2.1 Site Location Models

The basic approach to this application involves the creation of a mathematical model and its application to the region in question (Savage, S.H., 1990). There are two methods of dealing with the problem.

The first method requires the creation of site location models using logistical regression techniques in a statistical analysis package, such as SAS. The technique allows a binary presence/absence indicator of an archaeological site to be used as the dependent variable and various other environmental factors such as slope, distance to water, elevation, to be treated as independent variables (Savage, S.H., 1990, p. 26). However, this method contains some contradictions in its operational assumptions[3] thus increasing the possibility of errors being introduced (Savage, S.H., 1990). Some projects that have adopted this approach are those conducted by Marozas and Zack, in 1987, Warren, Oliver, Ferguson and Druhot, again in 1987, and Warren, in 1989 (see bibliography).

The alternative method, developed by Savage in 1989, is that site location is used as the dependent variable in a stepwise multiple regression model. That is, "the model uses stepwise multiple regression to isolate the various environmental factors which are significant contributors to known site locations" (Savage, S.H., p. 27[4]).

1.2.2.2 GIS Procedure Related Studies

This category involves only a limited number of studies examining the implications arising from the use of GIS in archaeology, particularly the acuracy of the results obtained (Savage, S.H., 1990).

For istance, Zubrow, while working on a study on the development of demographic models, in 1988, found out that "while simulating alternative settlement patterns, without changing the parameters, differences in resulting migrations should occur. It appeared to be a consequence of the order that one entered the initial centers or population concentrations into the networks of ARC/INFO" (Zubrow, E., 1988, in Savage, S.H., 1990, p. 28).

Zubrow attributed the problem to the fact that he was trying to model processes which are concurrent in nature on a computer which operated sequentially. His conclusion was that the problem will persist unless a method can be found which will allow concurrent processes to be modelled concurrently (Savage, S.H., 1990).

In another example, Kvamme (1988[5]) demonstrated that the scale of data collection and the degree of generalization could affect the results of archaeological analysis using GIS, a point which, in his view, many other researchers had overlooked (Savage, S.H., 1990). Specifically, in his study he compared digital elevation models (DEM) produced by two different agencies. They were available at different scales and dissimilar smoothing algorithms had been employed repectively by each one of the agencies for their creation. These dissimilarities in the quality of the data provided considerably affected the result of the archaeological site location study that was subsequently conducted (Savage, S.H., 1990). In 1989, Savage extended Kvamme's conclusions by demonstrating that variations may exist even in data deriving from a single source. In this case, the problems occurred on the boundaries of map sheets (Savage, S.H., 1989).

1.2.2.3 Studies on Larger Theoretical Concerns

Prior to the adoption of GIS in archaeological research on social organisation, spatial clustering and territoriality was examined by using advanced statistical techniques such as spatial autocorrelation and cluster analysis. These techniques were not only difficult to apply but the interpretation of the results produced also posed significant problems, forcing researchers to declare a status of a methodological dead-end (Savage, S.H., 1990). The ability of GIS to enable researchers to reference their data spatially and to interrelate information using mathematical and Boolean methods has since opened new horizons for investigation.

For example, by using early historic contact dates and the hydrology of New York state, Allen modelled diachronic aspects of trade patterns using the ARC/INFO GIS (Allen, M.S.K., 1990).

In 1988, Zubrow developed a number of models to study the spread of colonial population through New York state, treating the various river valleys as migration corridors. The results obtained were later compared with existing historical documentation (Zubrow, E., 1988).

While investigating the topic of existing GIS applications in archaeology, one is also left with the feeling that a number of projects remain unreported (see for example Zubrow, E.B.W., 1990a) or partially reported (for example, Powlesland, D., 1991). This should be borne in mind when considering the following classification of the best known GIS applications in archaeology.

1.2.3 GIS Applications in Archaeology

In section 1.2 the three distinctive lines of research in the field of GIS and archaeology were presented. What follows is a subcategorisation of these applications at a more detailed level in order to examine the specific GIS applications within these research areas.

The work that has been documented thus far in various publications can be classified in five distinct categories: (1) General, (2) Methods and Principles, (3) GIS/Remote Sensing, (4) GIS/Modelling, and (5) DTMs.

1.2.3.1 General

In this category we can classify two papers, one by Ferguson (1986) and one by Miller (1986) who both presented descriptions of available commercial software (Harris, T.M. and Lock, G.R., 1990). Kvamme (1986) also presented an overview of GIS software suitable for archaeological data management and research.

1.2.3.2 Methods and Principles

In 1985 a number of papers on the methods and principles governing the application of Geographic Information Systems in archaeological research were presented. Kvamme published two papers, one documenting GIS techniques for archaeological regional analysis (Kvamme, K.L., 1985a) and one on the fundamental concepts governing the application of GIS spatial analysis techniques in archaeology as well as the research potential arising through such methods (Kvamme, K.L., 1985b). Gill and Howes (1985) presented the methodology of employing GIS and surface samples to conduct intra-site distributional analyses and Ferguson (1985) addressed the theoretical concept of identifying patterns of prehistoric cultural adaptation through the use of GIS (Harris, T.M. and Lock, G.R., 1990).

T. Harris (1986) has stressed the need for archaeological data handling at a regional level. Similarly, Lock and Harris (1991), and Hinge (1991) called respectively for an integration of spatial information in the SMRs through the adoption of GIS technology. Hinge has gone further to mention the possibility for GIS intra-site modelling, albeit without presenting a full discussion of the subject (Hinge, P.D., 1991). Arroyo-Bishop (1991) has also announced the intention of the ArcheoData Project to incorporate a GIS in order to enhance its functionality and potential.

1.2.3.3 GIS/Modelling

As early as 1985 T. Harris had commented on GIS based archaeological data retrieval and its use in predictive modelling (Harris, T.M., 1985). Wansleeben (1988) conducted regional modelling based on environmental data in the Netherlands and in 1990 there were as many as four projects working on the subject of regional predictive modelling (Carmichael, D.L., 1990; Savage, S.L., 1990; Warren, R.E., 1990; Zubrow, E.B.W., 1990b).

Temporal data modelling was conducted by Allen (1990) in the eastern Great Lakes region, USA and there have been another five projects which have developed site classification models for regional site management purposes (Altschul, J.H., 1990; Green, S.W., 1990b; Hasentab, R.J. and Resnick, B., 1990; Jackson, J.M., 1990; Williams, I., Limp, W.F., Briuer, F.L., 1990).

1.2.3.4 GIS/Remote Sensing

In this category we can classify the work of Donoghue who used GIS technology in order to process remotely sensed data pertaining to wetland archaeology (Donoghue, D.N.M. and Shennan, I., 1988; Donoghue, D.N.M., 1989) as well as that of Madry and Crumley who have used remote sensing techniques to develop predictive models in the region of the Arroux River Valley, in Burgundy, France (Madry, S.L.H. and Crumley, C.L., 1990). Finally, Peterman (1990) announced the first application of GIS in Middle Eastern archaeology by combining remote sensing and GIS techniques for the digital mapping of the Transjordan.

1.2.3.5 Digital Terrain Models (DTM)

There is only one prominent example documented in this category, namely that of T. Harris (1988) who, having outlined the principles of DTMs and their use for archaeology and regional planning, demonstrated a method by which he used a DTM as a landscape base over which he draped archaeological information.

Reviewing the involvement of GIS in archaeology, described in the previous pages, two main points emerge. The first is that "predictive archaeological location modelling, with its vast data, computational, and cartographic needs, has thus far been the predominant application of GIS in archaeology" (Kvamme, K.L., 1989, p. 166). This is a view also shared by Savage (1990), who identified site location models developed primarily for cultural resource management purposes as the area of research on which most papers have been written to date (Savage, S.H., 1990).

The second point to be made is the absence of any GIS research dealing with the single site and its contents. In fact, the neglect of the single site is apparent both in the literature pertaining to the creation of the databanks, mentioned earlier in this section, as well as in the documentation of the GIS applications in archaeology, with two exceptions.

Dominique Powlesland (1991) has presented a system for the recording and analysis of the Heslerton excavation in North Yorkshire. The aim of the system is to provide a continuous data flow which will enable archaeologists to manipulate retrieved site information from the excavation stage to final publication. The Heslerton system contains several novel aspects, such as three dimensional recording, standardization in terminology, use of codes, and integration with graphics. However, there are some proplems associated with it as well.

Powlesland claims use of the relational data model for the recording of the primary archaeological data. One of the fundamental concepts of relational databases is the absence of data redundancy (De Albanese, L., 1988; Healey, R.G., 1990). Yet, in the model provided, the context record contains such redundancy as well as a violation of Codd's 3rd normal form (see Howe, D.R, 1983; Oxborrow, E., 1988). The general format of the main tables has resulted in an inflexible model which appears to be incapable of accommodating the whole range of information associated with an excavation. Hence there is a need for separate databases for the photographic record, faunal remains, etc., which limits the potential for complete data integration. Finally, there is no provison documented to integrate the system with any other analytical software (e.g. statistical packages) which would considerably enhance the link between analysis and publication.

It is very difficult to judge the Heslerton system from the available report since it is described in very concise terms (for example, it is not clear whether the GEOBASE system mentioned is a GIS developed by the author or just another graphics package). Without, however, intending to diminish the valuable contribution of the Heslerton Project to the "single site approach"[6], it can be argued that the Heslerton system is still far from the desirable format in which archaeological data should be captured.

Daniel Arroyo-Bishop (1989; 1991) has developed another system for the recording and analysis of archaeological data, called ArcheoData. The fundamental principles underlying the creation of the ArcheoData system constitute the most complete set of guidelines for what an archaeological information system should involve (see Arroyo-Bishop, D., 1989). Already using remarkably detailed pro-forma recording sheets and a revolutionary graphics interface utilising bar codes (Arroyo-Bishop, D., 1989), ArcheoData now intends to adopt GIS technology for spatial recording in the near future (Arroyo-Bishop, D., 1991).

The disadvantages of the ArchaeoData approach are (a) the absence of any attempt to integrate the data-base with other forms of data analysis (e.g. statistical packages, spread-sheets), (b) the in-flexible hierarchical data model adopted for certain data categories (e.g. the inventory record), and (c) the absence of any intention to expand the facilities in order to provide for the publication of archaeological reports or to incorporate a number of types of additional information, such as conservation records, museum inventories, and bibliographies. There is a stated intention to provide for specialist files (Arroyo-Bishop, D., 1989) but no clear documentation of the steps taken in that direction has been provided.

Concluding this section on the history of GIS applications in archaeological research, a discussion of current approaches to large scale regional research will be made in order to identify the reasons for the noticeable lack of intra-site applications.

1.2.4 Current Approaches to Large Scale Regional GIS Research

Faced with the enormous and ever growing amount of archaeological information collected, the creators of the first databanks dedicated their efforts to accumulating only the essential data on archaeological sites which would allow for an efficient cultural resource recording (and consequently, management) of the ancient heritage. As a result, they have created a reliable source of data with great potential for providing feedback for large scale regional studies only (Lock, G.R. and Harris, T.M., 1991). This resource was greatly exploited by GIS applications, which either benefited directly from the spatial element already incorporated in those databanks by the provision of site coordinate references (e.g. Plog, F., 1981; Rieger, A., 1981; Scholz, S.C. and Milion, M.G., 1981) or by introducing the spatial element to an existing databank at a later stage (e.g. Altschul, J.H., 1990; Williams, I., Limp, W.F., Briuer, F.L., 1990). In other words, the tradition developed in databank applications of by-passing the recording of the single site (with the exception of the few examples mentioned above) has also been taken up by the GIS based studies that have followed. One is tempted to conclude that this was actually done because of the resource inputs required for the re-registration of all known sites in a very detailed manner, or because the ability of GIS to handle efficiently large scale spatial studies has attracted enthusiastic attention at this initial stage of their application in archaeology. Indeed, Harris and Lock, commenting on their proposal for the adoption of GIS by UK archaeology, wrote that:

> "In many respects our perception of the potential role of GIS in this country [UK] goes beyond the specific use of GIS techniques for individual site project work. We anticipate that some archaeologists will, as with the diffusion of computing and quantitative techniques, look to implement GIS in regard to their own specialty areas. ... Our perspective, however, is to focus not so much upon the adoption of GIS as an additional tool in the archaeologist's analytical armoury for individual project work, important though it is, but on the integration of GIS in the archiving and analysis of the archaeological resource at the regional and cultural level. ... What is important in this respect is that the long term recording and inventorying of this heritage by UK archaeologists has resulted in the development of comprehensive regional and national computerized databases of archaeological sites. The existence of this rich archaeological record and the far-sighted recording of sites in regional and national archives suggests that the advent of GIS in the UK could have an impact at a level greater than that of site specific applications"
> (Harris, T.M. and Lock, G.R., 1990, pp 36-37)

In fact, the point that GIS are suitable for intra-site applications has been stated (e.g. Harris, T.M. and Lock, G.R., 1990; Hinge, P.D., 1991; Green, S.W., 1990a) but no comprehensive effort has been made to examine what this type of application really entails. Besides the above reference, Green, in the introductory chapter of the first book on the subject of GIS and archaeology writes that "although we have no examples in our book, we would argue that GIS could be applied in classical [sic] archaeology as it is excellent for mapping large areas and sites" (Green, S.W., 1990a, p. 7).

The standpoint adopted in this thesis is that in order to improve the quality of the archaeological record and the functionality of GIS within archaeology, the beginning should be made from within each individual site. If GIS technology is applied directly from the start of the excavation not only will it improve the quality of the recording and analysis of the site, but it also will provide the basis for a more complete and accurate cultural resource databank which, in turn, will facilitate improved regional studies. The lack of such a strategy is evident even in North America. Ebert has written that "in fact, no state in the U.S. has an archaeological site locational database that is automated in GIS format" (Ebert, J., X-News: geovax comp.infosystems.gis, 1992). His complaint is seconded by Chris Hermansen from Canada who states that forest companies in British Columbia are forced to collect some "obvious" archaeological information but thus far there is no method or standards imposed. As a result each company follows a separate approach (Hermansen, C., X-News: geovax comp.info-systems.gis, 1992).

Especially in countries where archaeological recording has not even reached the central database level, as in the case of Cyprus, it becomes even more imperative to lay a firm basis on which such a future system can be built. It may be admitted that it will take a considerably longer time before such a system is capable of conducting large scale spatial analysis, but when that stage is reached the research will be based on firmer ground and it will possess a much more complete and accurate archaeological set of data. The importance of such a fundamental notion cannot be stressed enough, especially when considering the vast amount of information deriving from the East Mediterranean region and the Middle East, information that not only extends back a considerable number of millenia but also lies dispersed in the archives of a substantial number of international archaeological projects.

1.3 Computer Based Graphical Excavation and Analysis

It is also necessary at this stage to include an overview of the use of computer aided design (CAD) based systems in archaeology in order to clarify the distinction between a CAD-based and a GIS-based application.

CAD systems were created as an automated aid to the manual graphic techniques employed by many technical disciplines but primarily for engineering and architecture. Their main abilities are to produce high quality line drawings characterized by geometric accuracy (e.g. fine curves, perfect line joints etc.). Adding annotation, shading, and symbolism and the ability to isolate features from a master layer or bring different layers together are a few more desirable facilities offered by these systems (Cowen, D.J., 1990). Consequently, CAD systems can also be used for the portrayal of geographic data which can be digitized from available base maps.

With particular reference to archaeology, CAD systems have found several areas of application but primarily there are four distinct types of application: (1) cartographic display, (2) automated draughting and planning, (3) solid modelling, and (4) architectural design.

1.3.1. Cartographic Display

The COMPASS system which was developed for archaeological surveying and mapping purposes is an example of this type of application. It makes use of two CAD systems (i.e. MacDraft and MacDraw) and has been applied in archaeological research in South-east Asia (Weiss, A., 1989) for the automated mapping of areas of archaeological interest.

1.3.2. Automated Draughting and Planning

Automated draughting and planning is another area which has much profited by the use of CAD systems. Alvey and Moffett have generated PLANDATA for the digitizing and retrieval of single context plans (Alvey, B. and Moffett, J., 1986) and the York Archaeological Trust uses AutoCAD, a widely used commercially available package, to digitize plans for pre-publication drafts (Reilly, P., 1991; Richards, J., 1991).

Alvey has improved even further the concept of single context draughting by developing a system called HINDSIGHT. This system uses AutoCAD as its front end for graphic display while it simultaneously makes use of a DBASE II database, which stores information regarding the excavated contexts. The output provided is a "three-dimensional" (rather an exploded re-presentation) of the excavated contexts placed in stratigraphic sequence (Alvey, B., pers. comm., 1989;

Alvey, B., 1989). Tim Williams (1991) also uses AutoCAD for graphic reconstruction of the Harris Matrix.

At this point it is useful to mention the existence of computer aided mapping (CAM) systems which also have applications in both areas described above (i.e. cartographic display, and automated draughting and planning). The main difference between a CAM and a CAD system is that the former can also be linked to a database, in a rudimentary fashion. In this sense, Alvey's HINDSIGHT could be classified as a CAM system, although a full report on its facilities and function is still to be made. Perhaps GIMMS is a better example (see Waugh, T.C. and McCalden, J., 1983) of a CAM system. Despite the fact that it is basically geographically oriented it also offers a wide range of statistical representations and Gray and Morrison (1988) have applied it to the creation of a historic atlas of Scotland.

1.3.3. Solid Modelling

Gill Chapman (1991) has recommended AutoCAD 11 as a surface/solid modeller to be used by the Lancaster University Archaeological Unit. Although AutoCAD is not the ideal package for solid modelling, the fact that some of its features have become market standards, in addition to the number of software packages that have been developed with the option of interfacing with AutoCAD, has in this case counted in its favour.

The Furness Abbey Survey Project is yet another such application (see Delooze, K. and Wood, J., 1991). Here AutoCAD is used to create the reconstruction drawings which will later be linked to the Plant Design Management System (PDMS) database.

1.3.4. Architectural Design

Finally, the fact that CAD systems have been developed primarily as architectural and engineering design toolkits has made them ideal for archaeological applications where architectural features are to be studied or represented. A prime example is the use of the AutoCAD package by Manolis Corres (1989) to produce the static study during the reconstruction of the Parthenon at the Acropolis in Athens.

1.4 GIS vs CAD/CAM systems

The purpose of the references to the previous applications is not to conduct an in-depth examination of the archaeological applications of CAD/CAM systems but rather to provide some indicative examples of their use in research work in order to highlight their differences with GIS.

The definition given to CAD systems is that of a graphics system (Cowen, D.J., 1990) or a graphics/mapping system (Savage, S.H., 1990). CAD systems possess the ability of depicting map elements, select parts of it, and assign symbolism of various types (e.g. shading, line types, point symbols). Nevertheless, for these actions to take place they have to be assigned interactively by the user. In other words, CAD systems do not possess the facility, among others which will be discussed below, to fully interface with a database (Cowen, D.J., 1990). CAM systems, on the other hand, maintain such a rudimentary database linkage but are still considerably lacking in GIS functionality for reasons reflected in the definition of a Geographic Information System which has been given in the previous pages.

Moreover, CAD/CAM systems cannot deal with the topological relationship between map features (e.g. which lines form part of which polygon). Such a feature is essential for spatial analysis and overlay to be performed and is only found in GIS systems.

The superiority of GIS over CAD/CAM systems relies to the ability of the first to (a) bring together data sets into a common geographic frame of reference, (b) integrate cartographic display and data-base management with spatial analysis, and (c) provide facilities for combining data layers, using map overlay techniques in order to create new data sets.

The above discussion on the differences between CAD systems and GIS could lead to the conclusion that one should consider very carefully whether there is a need to employ a GIS or a CAD/CAM system. For the intra-site recording of a classical site for example, AutoCAD would be an excellent tool for drawing architectural features such as columns, facades, etc. If on top of that a spatial analysis was needed, a GIS would have to be operating alongside AutoCAD. That, however, is not necessarily the case any more since recently GIS technology has been merged with CAD applications in a fully integrated fashion, to form a system that offers both the high graphics quality of CAD and analytical power of GIS.

Two of the major vendors of GIS software, INTERGRAPH and ESRI provide now interfacing platforms with CAD systems. INTERGRAPH has adopted an upward application by which the user starts with the MICROSTATION CAD system and with the gradual addition of several software components reaches GIS status (Stewart, N., 1992, pers. comm.). ARC/INFO on the other hand uses ArcCAD as a sideways or peripheral component which is capable of exchanging information between the two systems (i.e. ARC/INFO and AutoCAD) in a fully integrated fashion (CADDESK, 1992).

1.5 Purpose of the Thesis

Despite the many benefits they have to offer, GIS packages possess a major disadvantage, in that they are still very expensive to purchase. Considering the restricted budget under which most archaeological projects work the adoption of a GIS becomes a relatively expensive venture on the one hand, yet a very desirable prospect on the other because of the potential benefits it offers.

The benefits made immediately available to archaeologists (and consequently, to archaeology in general) through the use of a GIS are manifold and these have to be set against the financial costs involved.

To start with, there is the prospect of recording the data pertaining to an excavation more efficiently and meaningfully. The use of a GIS not only manages to provide a graphic (or cartographic) display of the excavated material, but the system also records locational references, whether in actual geographic coordinates or in relation to the excavation grid. Thereafter, any archaeological inquiry can be answered by the system within a realistic spatial framework. For example, if the system is presented with a question regarding the contents of a given building it will provide not only a list of the finds but also the exact location in which they were retrieved and the chronological period to which they are attributed.

Another advantage offered by GIS is their ability to organise data sets into successions of information layers that can later be brought together in a variety of combinations. This facility caters for the need of a "three dimensional"[7] recording of archaeological information. For example, in an effort to separate the in situ material from the intrusive ones, a given context can be studied as a succession of the individual layers which it incorporates. In addition, the option remains open for the introduction of time as a fourth dimension in an effort to conduct archaeological analyses within a time-space framework.

Finally, since GIS are capable of handling large amounts of data they are also ideal for a number of large scale archaeological applications such as cultural heritage management, national archaeological records, intra-site studies, monitoring environmental change and its effect on archaeological sites, surveys, reconstruction of past environments, and simulation studies, among others, which model a site under the prism of a changing physical and chronological background.

As already stated, the perspective adopted in this thesis is that to date large scale archaeological applications of GIS have been favoured at the expense of single-site applications. If we are to improve matters it is not possible just to start from developing end results (i.e. regional or national records) but we should first concentrate on the source of our information, the excavation of the single site. In other words, this thesis proposes an upward implementation of methods and techniques instead of a downward one.

It has been argued that the widespread adoption of GIS by archaeologists is a very desirable prospect (Harris, T.M. and Lock, G.R., 1990). To achieve this aim the majority of researchers in the field have first to be convinced that it is worthwhile to invest in financial and educational resources, in order to acquire the proper level of expertise required by the use of Geographic Information Systems.

Consequently, the field archaeologist would like to see a system that caters for the accurate collection, organisation, distribution, and manipulation of the collected data. This system should be able to answer a number of standard queries and at the same time be able to respond to a variable number of inpromptu enquiries. As a result, the time required for data analysis should be considerably decreased while at the same time the end quality of the conducted studies should increase, thus justifying the effort and investment required. New research opportunities should become evident and ideas for improving existing excavation strategies should surface. Training should be provided on the use of the system and ideally a user-friendly interface should exist ensuring easy access to the facilities of the system.

It is also important to ensure that the GIS in use will not operate in a purely stand-alone manner but that it is capable of being interfaced with other computer software that may be employed by the excavation, in an integrated and flexible fashion. This will ensure the free flow of information throughout the various software packages involved.

Thus, keeping in mind that the primary aim of the individual archaeologist is to excavate his site and eventually publish it, prior to becoming involved in any form of large scale project, this thesis serves a threefold purpose: (a) To provide an example of an intra-site application of GIS, as opposed to a regional one for which most systems are designed to cater, (b) to supply the methodology which will link other computer applications, possibly already employed by archaeologists, with a GIS in a fully integrated Archaeological Information System (AIS), and (c) to design this system in such a way that it will be capable of accepting a relatively limitless number of new components (i.e. hardware and software) as the research requirements increase. It should also ensure that the individual components remain independent for lower level applications (i.e. applications that will involve a limited number of hardware and software components, depending on the nature of the excavation).

In this study emphasis has been placed on the development of a system that would correspond to the realities of the prehistoric record. That is, the nature of the evidence collected is highly fragmentary and therefore the system employed should cater for the individual characteristics of the given excavation as well as providing a mechanism for its detailed recording.

The site chosen for implementation of this research is the site of Kissonerga in W. Cyprus. The site's major characteristics, archaeological importance and problems are concisely presented in chapter II, along with a summary of the archaeological work that has already been conducted there.

KAIS (Kissonerga Archaeological Information System) is the name of the system that has been developed to capture, organise and finally, analyse the excavated data. An overview of the concepts around which the system was built as well as the levels of operation of the system are presented in chapter III.

The first step towards the development of KAIS was the construction of a relational database structure for the storage and analysis of the primary archaeological data. The methodology for this and the logic underlying the creation of the database structure are discussed in chapter IV, together with a summary of the rules governing such a process.

Chapter V demonstrates the methodology developed for transferring site plans in digital form into a GIS. The major problems involved in such an operation are addressed, although it is not necessarily possible to provide straightforward solutions in all cases.

Chapter VI is concerned with the analysis of archaeological data with the aid of a GIS. This however is not achieved independently, but in an integrated way by linking the database with the GIS, to provide more flexible retrieval and analytical capabilities.

It has been mentioned above that the ultimate aim of each excavation project is to publish the results of its activities. A complete AIS must address publication issues as the final stage in an analytical process. Therefore, chapter VII discusses a number of ways in which computers and information technology (IT) are able to facilitate an efficient approach to timely publication. Certain practical issues are presented along with some which have an ethical dimension and a way forward is proposed.

Finally, the advantages of the system, together with its limitations, are summarized in chapter VIII. A list of proposals regarding the future enhancement of the system is also provided, firstly to demonstrate that development of KAIS can continue beyond the limits of this thesis and secondly, to provide some insights for future researchers.

Endnotes

[1] In this discussion some USA government funded programmes have been excluded. These projects were undertaken by agencies such as the Forestry Department or the National Park Service. Their aim was to conserve archaeological information associated with sites threatened by development from the afore-mentioned agencies. For a full discussion on the subject see Gaines, S., 1984.

[2] These are studies which examine possible implications arising from the use of GIS in archaeology. Particular emphasis is placed on the study of the accuracy of the results that are obtained (Savage, S.H., 1990).

[3] See Savage, S.H., 1990, pp 26-27.

[4] This method is fully documented in Savage, S.H., 1989.

[5] The 1990 article by Kvamme with the same title is a revision of this original paper.

[6] In reality, the present data model may serve the needs of the particular Project most adequately. This thesis in fact argues favourably the point that each archaeological project has its own distinct "idio-syncrasy", and that any system designed should be taking into account the nature of both the project and the information involved.

[7] In fact, what is called a 2.5-D representation can be achieved in this case. The subject is more fully discussed in the following chapters.

CHAPTER II

The Site

2.1 Short History of the Lemba Archaeological Project

The Lemba Archaeological Project (LAP) was founded in 1976. Its purpose was the study of developments in the prehistory of Cyprus by excavating three sites: Lemba-*Lakkous* (LL), Kissonerga-*Mylouthkia* (KMyl) and Kissonerga-*Mosphilia* (KM) and by conducting intensive surveys at the Ktima Lowlands area and the western slopes of the Troodos mountain range (see figure 1). The aims of the Project are best summarized in the words of its director:

> "To provide the first plans of 4^{th} -3^{rd} m BC chronologically overlapping settlements and their associated cemeteries: to carry this out in the West of Cyprus where there may be an extension of population from the East, and where there is an anomalous density of sites and highly stylised figurines unique to the island; to determine site function and context from studies of their spatial organization and their relationship with other communities and their environment; to investigate specifically the advent of metal, the mechanism of population shift and in more general terms two formative periods, the Sotira/Erimi and the Erimi/Early Cypriot cultural transitions; and finally, by integrating survey evidence into a dated framework provided by excavations, to consider the prehistory of West Cyprus in its insular and East Mediterranean setting" (Peltenburg, E.J. et al, 1985a, p.2).

The Project's field station was established at the village of Lemba with the intention of housing several

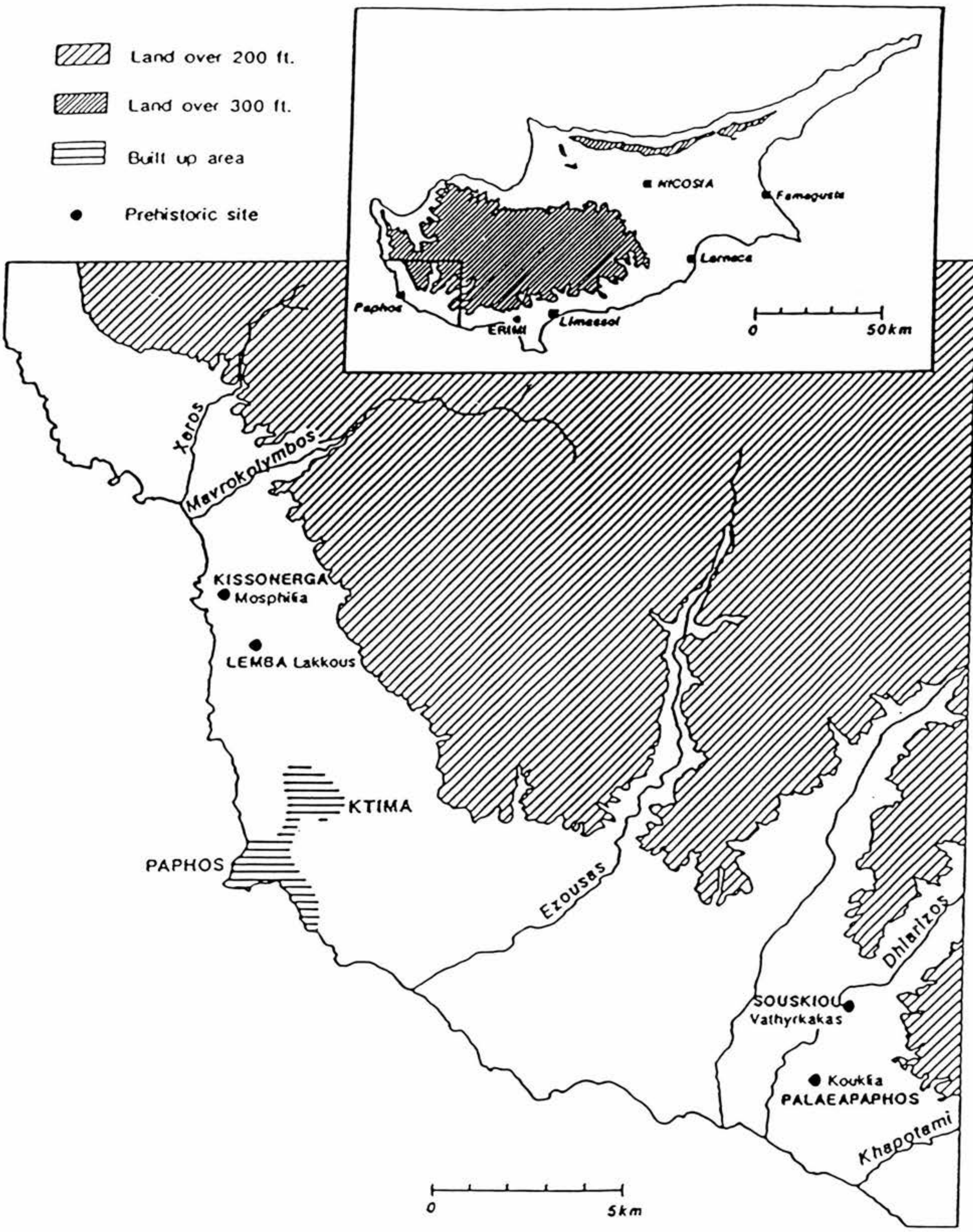


Fig. 1. LAP's area of activities

teams of specialists throughout the year to examine the excavated material and conduct experimental work at a location as near as possible to the relevant site. Thus, associations between material and context would become more direct and observations more objective.

Since the beginning, apart from the site supervisors and excavators, the Project involved twelve specialists to deal with the finds. The areas of their expertise are ceramics, chipped stone (flints), flotation, faunal remains, small finds, physical anthropology, oral biology, mollusca, metallurgy, pollen analysis, wood identification and geomorphology. During the 1989 season it was decided that computers should be introduced to facilitate even more advanced methods of material analysis and experimental work. Consequently, the author joined as the thirteenth member of this team and a year later the first version of KAIS (i.e. **K**issonerga **A**rchaeological **I**nformation **S**ystem) was made available to the Project (Papailiopoulos, D., 1988). The site on which KAIS was fully implemented was Kissonerga-*Mosphilia* (since 1990 referred to as Kissonerga only).

2.2 Site Location

The location of Kissonerga is about 6 km North of Paphos, in Western Cyprus, and approximately 500 m NW of the centre of the modern village of Kissonerga (see map 1). Its geographical reference, as given on the 1:5,000 cadastral map of Cyprus (Series D.L.S. 17 (D.O.S. 155), sheet 45/XVIII, edition 1 D.L.S./D.O.S. 1978), is VD448540 (lower left corner).

The site is part of what is known as the "Lemba Cluster" which consists of four sites all attributed to the Chalcolithic period of the island. These sites are: (a) Lemba-*Lakkous*, (b) Kissonerga-*Mylouthkia*, (c) Kissonerga-*Mosphilia* and (d) Chlorakas-*Palloura*. All the afore-mentioned sites are "within 4 kms from each other but not intervisible" (Peltenburg, E.J., 1979, p.79).

Peltenburg has classified Kissonerga as a type 3 settlement, that is, "gently sloped settlement beside stream" (Peltenburg, E.J., 1979, p.78). It is indeed located on the northern bank of the Argakin tis Skotinis river and in common with all other sites of the same type, it does not spread along the riverside, but rather it extends inland (figure 2). Lying at about 45 m above sea level its uppermost strata have been heavily disturbed by erosion processes (land erosion on the island has been noted as "very severe") and by agricultural terracing, both ancient and modern. Terrace steps in the area can be cut as much as 4 m deep (Peltenburg, E.J., 1979).

Fig. 2. Aerial photograph of the site of Kissonerga

Kissonerga, as well as all the other sites of the Lemba Cluster, also belongs to the "Erimi Group", as identified by Porphyrios Dikaios in the 1930's[1]. The site was first noted by Megaw in 1951, later to be confirmed by Hadjisavvas' surveys in the Ktima Lowlands. Its great importance had been long suspected but only after intensive survey and trial excavation by LAP was the full scale of its potential appreciated. In order to convey the site's significance to the reader, it may be useful to offer a brief review of what is known of the early prehistory of Cyprus and the problems associated with the archaeology of those periods; this overview is confined to its relevance to the importance of the particular site under study.

2.3 Early Prehistory of Cyprus and Associated Problems

In the 1930's and 40's, the then Director of Antiquities, Porphyrios Dikaios made a substantial contribution to Cypriot archaeology. He exposed and investigated the Neolithic and Chalcolithic phases of the island. Two key sites that he dug have lent their names to the relevant cultures. Sotira characterizes the Neolithic (see map 2) and Erimi (see map 3) the Chalcolithic (Karageorghis, V., 1990).

In the years to follow, the Neolithic period attracted most of the attention of the prehistorians, particularly because the evidence available demonstrated, at least in the archaeological record, a considerable chronological gap between the aceramic and the ceramic[2] phases of that age (Peltenburg, E.J., 1982). Erimi, on the other hand, was the first known site to produce copper objects (Peltenburg, E.J., 1982). Therefore, Dikaios dated it to the Chalcolithic period and within this phase he identified only two sub-periods, namely Chalcolithic I and II. This assumption attributed to that intermediate period (sic) only a very limited chronological span, that again created a considerable time gap until the beginning of the next phase, the Bronze Age (Karageorghis, V., 1982).

Based on Dikaios' observations, archaeologists for years desperately searched for an interpretation of excavated sites that apparently post-dated Erimi's Chalcolithic II period but at the same time antedated the dawn of the EBA[3] (Early Bronze Age) on the island. Thus, the gap between the end of the Chalcolithic period (Chalcolithic II) and the beginning of the EBA was clearly depicted in the archaeological record.

The discovery made at Souskiou in 1951 (Peltenburg, E.J., 1979) was of considerable importance. At first thought to be a single cemetery, this proved to be three cemeteries associated with a heavily eroded settlement located nearby. The study of its material led to the conclusion that the Chalcolithic period was not only far from being a short-lived transitional phase but that it constituted a rich, distinct culture of its own. It had contributed considerable innovations in the areas of crafts, architecture and social customs.

If Souskiou marked the significance of the Chalcolithic period, another discovery, the cemetery at Philia-*Vassiliko*, heralded the closing stage of that period and the beginning of the subsequent one, the EBA (see map 4) (Karageorghis, V., 1982). The characteristics of "Philia Culture" were so distinctive that theories of invasions from Anatolia were developed to explain the beginning of the new era in Cyprus. The archaeologists were now called upon to prove whether or not the colonization theory stood or whether there were signs of internal cultural development which would signify a smooth transition between the two periods. In this exercise the Lemba Archaeological Project has played a paramount role.

2.4 The Importance of Kissonerga

For many years the West part of Cyprus was considered as culturally poor in comparison with other regions of the island (Peltenburg, E.J. et al, 1982).

Therefore, apart from surveys[4] no other kind of archaeological fieldwork was conducted in the region. As a result the sites remained there for future excavation with the most advanced techniques possible to-date (unfortunately, not before they suffered severe disturbance by agricultural activities).

The settlement pattern in Cyprus' prehistory, as it can be visualized from the evidence at hand, has been established in the following manner: During the Neolithic period, most of the settlements were located in the North-centre; in the Chalcolithic, a considerable shift occurred to the South and Southwest. Later on, in the Bronze Age, another relocation took place, this time to the central regions of the island with the most prominent sites situated around the Troodos massif, where rich copper ores existed (see sequence of maps 2-4).

Kissonerga therefore, is located amidst the chalcolithic cluster of sites in western Cyprus and it is also the largest excavated to-date, occupying a surveyed area[5] of c. 12,000 m^2 (Peltenburg, E.J., 1979). Nine years of continuous excavation proved it to be a long lived multi-period settlement. Five periods have thus far been identified. Period 1, Late Neolithic (4,500-3,800 BC[6]), of which only sherds have been found; Period 2, Early Chalcolithic (3,800-3,500 BC), also identified by pottery remains and traces of possible buildings of flimsy construction, though some burials are also attributed to that period (Peltenburg, E.J., 1988a); Period 3, Middle Chalcolithic (3,500-2,800 BC), characterized by pottery, burials and architectural remains (buildings); Period 4, Late Chalcolithic (2,800-2,300 BC), of which both buildings and burials have been excavated and finally, Period 5, Early Bronze Age (2,300-2075 BC), identified by pottery, possible burials and recently, some standing features (material still unpublished[7]) (Peltenburg, E.J. and Project Members, 1986, Peltenburg, E.J., 1989b).

By the periods present and the relative chronologies given above, it should be noticed that Kissonerga, although chronologically attributed to the Erimi culture, also incorporates two transitional periods: that from Sotira to Erimi culture (Late Neolithic) and that from Erimi to the Philia[8] stage (Late Chalcolithic-Early Bronze I[9]). Bearing in mind this important attribute of the site, a period by period analysis follows, in an attempt to list all the considerable "firsts" that Kissonerga demonstrated.

2.4.1 Period 1 (LN)

Up to this point the Late Neolithic period could only be traced by ceramic assemblages found in the lowest strata of the site. No standing architecture has been revealed nor is it likely to be encountered in the future, at least in the lower (main) field excavated. Erosion processes must have been severe even in that period. Nevertheless, its detection testifies to the longevity of the site.

2.4.2 Period 2 (EChal)

This period is also distinguished by the presence of ceramics and some pits. Erosion was very heavy as in the preceding period, contributing to the destruction of any further evidence that might otherwise have existed.

2.4.3 Period 3 (MChal)

During excavations it was observed that unit 855 (see figure 3) incorporated old ceramic wares in direct association with novel architectural features. That was an indication of a possible cultural transition within the site (Peltenburg, E.J. and Project Members, 1987). The possibility is now being considered that the results of the study of the ceramic sequence in conjunction with stratigraphic evidence at Kissonerga

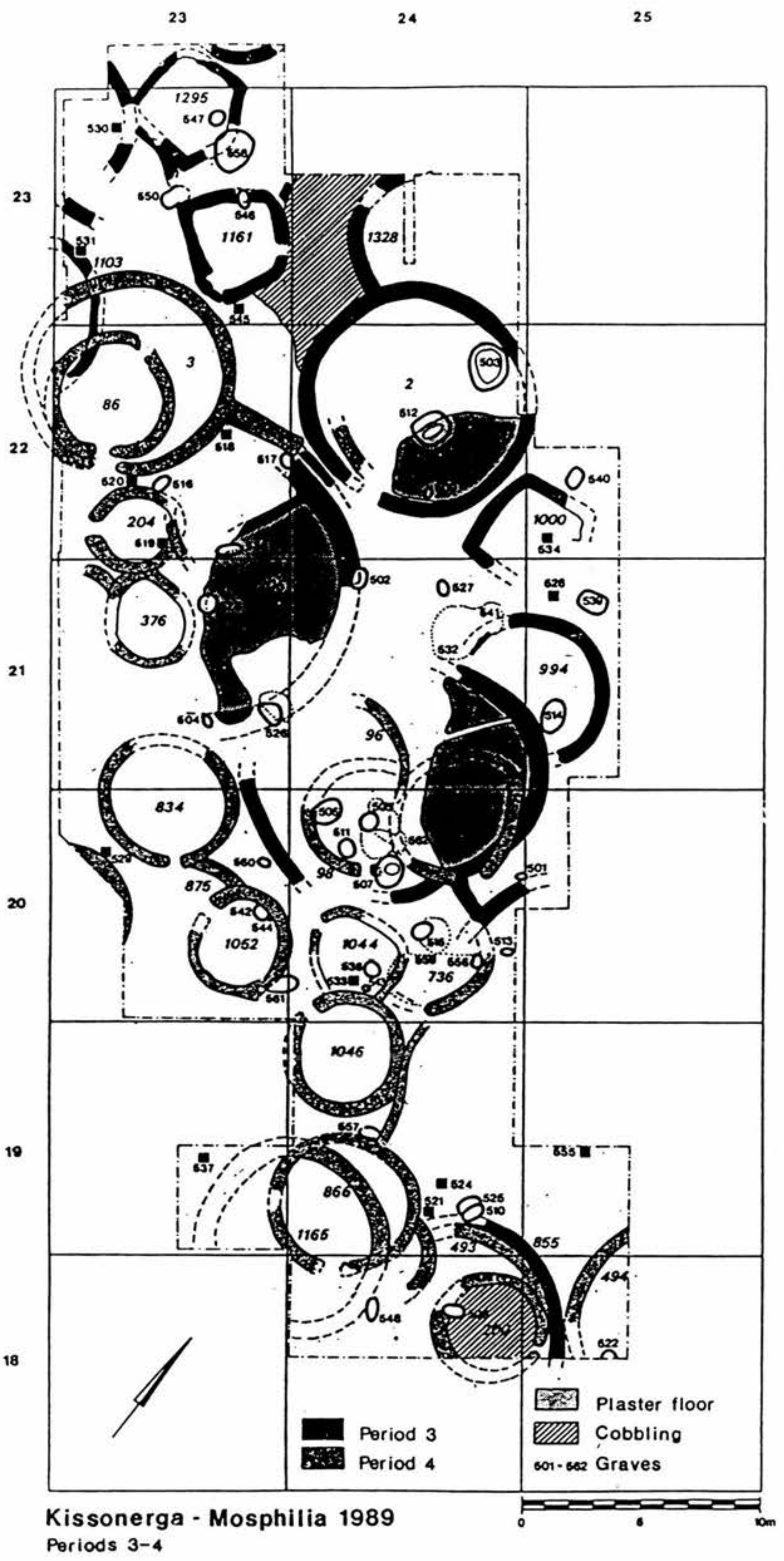


Fig. 3. General diagram of the Kissonerga excavation

call for a division of Period 3 into two sub-periods namely, 3A and 3B (Peltenburg, E. and Bolger, D., 1990, pers. comm.).

2.4.4 Period 3A (MChal)

Architectural remains have been encountered in the upper (secondary) field and of paramount importance is the square hearth of building 1016, which also demonstrates the radiating ridges so characteristically depicted in the building model of unit 1015 (see discussion of period 3B). Below it another building (B1547) was located and part of its floor had been stained with red ochre, the earliest such occurrence yet discovered in Cyprus.

The evidence from some of the graves attributed to that period is also impressive. Grave 554, in the upper field, was a child burial, containing a toilet shell bearing traces of malachite (a substance extracted from copper pigments) which was used for cosmetic purposes (Peltenburg, E.J., 1988a, Peltenburg, E.J. et al, 1988). Not only does this constitute one of the first cases of evidence for the use of copper in the island (let aside the knowledge that malachite could be used as a cosmetic), but it is also the first occurrence ever of cosmetics as grave goods in Cyprus. Parallels for such a practice exist only in Mesopotamia and the

Near East but these are attributed to later periods (Peltenburg, E.J., 1988a, Peltenburg, E.J. et al, 1988).

Another feature of grave 554 was the anthropomorphic slab[10] covering the body (Peltenburg, E.J. et al 1988), a tradition encountered also at Sotira (Dikaios, P., 1961). Here, therefore, the continuity of traditions originating in previous periods is attested, at least in burial customs.

2.4.5 Period 3B (MChal)

This is the period of Kissonerga's prosperity, as testified by the quality of the figurines uncovered and the evidence for the existence of foreign imports (Peltenburg, E.J. and Project Members, 1987). A flint blade and point have no Cypriot parallels. They probably originate from Syria or Anatolia. Obsidian, also discovered, is not a material indigenous to Cyprus (Peltenburg, E.J., 1988a). Period 3 is also characterized by the largest circular buildings of the Chalcolithic period in general (Peltenburg, E.J., 1988a). Building 206, with an estimated diameter of 12-15 meters, is by far the largest building of prehistoric Cyprus to be excavated (Peltenburg, E.J., 1988a). This building also possessed a red ochre floor and consequently, it is also classified as one of the earliest encounters of this particular feature in

Cyprus (Croft, P., in Peltenburg, E.J. and Project Members, 1987).

During the period the settlement expanded horizontally across areas previously unoccupied. This expansion was conducted in a very organized manner rather than in a haphazard one (Peltenburg, E.J. and Project Members, 1987).

With regard to the architectural remains, it was with great surprise that a number of rectilinear buildings were revealed (e.g. building 1000) (Peltenburg, E.J. et al, 1988, Peltenburg, E.J., 1989b). It is the first time such a discovery has been made, since the circular building is one of the dominant characteristics throughout chalcolithic Cyprus. Rectilinearity is encountered only in the Neolithic period (e.g. Sotira) or the Bronze Age (e.g. Alambra) and thereafter.

Another structure, building 994, is unusual in the sense that it demonstrates a red pise superstructure. Its poor quality whitewashed floor, although common in preceding and subsequent periods, is exceptional in the Middle Chalcolithic (Peltenburg, E.J. et al, 1988).

Finally, the first ovens of prehistoric Cyprus were also encountered during this phase at Kissonerga

(Peltenburg, E.J. et al, 1988).

The evidence deriving from burials shows the existence of a skull burial[11] (grave 528) (Peltenburg, E.J. and Project Members, 1987), bearing testimony that the Sotira tradition[12] (Dikaios, P. et al, 1961) continued well into the MChal. There was also the discovery of a possible live burial, the body being unnaturally distorted. The possibility of apparent death should not be excluded (Thomas, G., in Peltenburg, E.J. and Project Members 1987), but this find recalls some at Khirokitia where human sacrifices were encountered (Dikaios, P., 1953, Dikaios, P. and Stewart, J., 1962[13]).

Two flasks find parallels in the cemetery at Souskiou (LChal). A stone bowl, also found in the same context as the flasks, and bearing evidence of Cypriot manufacture, also has a parallel at the site of Vasilia (Bronze Age). The interpretation for the Vasilia bowl is that it is of Egyptian artistic influence (Peltenburg, E.J. et al, 1985b).

The most astonishing discovery, however, was the ritual deposit in unit 1015, which has since been much discussed[14]. A pot model (KM 1446) of a house full of figurines and other artifacts was the most important content of the deposit. It heralded the beginning of a tradition that is again encountered in Cyprus 1,000 years later in a tomb at Vounous (c. 2,000 BC) (Bolger, D. in Peltenburg, E.J. et al, 1988). This ritual deposit in unit 1015 is considered as a "final act" prior to the temporal abandonment of the site at the end of the Middle Chalcolithic (Peltenburg, E.J. et al, 1988). Subsequently, the area was utilized as a havara[15] quarry and as a burial site (Peltenburg, E.J. et al, 1988, Peltenburg, E.J., 1988a).

2.4.6 Period 4 (LChal)

In this period the evidence of Cyprus' foreign contacts becomes even more distinct in Kissonerga's archaeological record. Faience beads, obsidian, and a chlorite ladle attest to the intensity of such contacts since the materials they are made of are not indigenous in Cyprus. Moreover, the earliest previous instance in which faience has been encountered is in E.C. III Vounous (Peltenburg, E.J., 1988a).

That contacts between Cyprus and other lands were established is therefore evident. The direction of those contacts is now, however, becoming problematic. For example, copper spiral hair rings were thought of as originating from Anatolia. However, the discovery in grave 529, a child burial, of yet another copper spiral hair ring, makes this class of evidence more common in the Cypriot record than in the Anatolian one (Peltenburg, E.J., 1988a). This calls for the rethinking of some prevailing theories regarding contacts.

There is evidence of continuity in the material culture where MChal architecture is encountered together with LChal ceramics (Peltenburg, E.J. and Project Members, 1987). New architectural features are, however, found in association with other styles of pottery in other parts of the site, and indicate the nature of the transition that the culture underwent as it evolved between periods (Peltenburg, E.J., 1988a).

If there is one aspect of social life which, according to sociologists and anthropologists, is characterized by a very high degree of conservatism, it is that of burial customs. In direct contrast to this assumption, at Kissonerga, especially in the LChal, the diversity of funerary practices encountered is astonishing (Peltenburg, E.J. et al, 1985b). Summarizing those variations we have come across:

(a) skull burials in pit 911, where three skulls were excavated (Thomas, G., in Peltenburg, E.J. et al, 1988), again linking LChal Kissonerga with Sotira,
(b) a double inhumation in grave 539 in the same pit below the skulls (Thomas, G., in Peltenburg, E.J. et al, 1988),

(c) a surface burial in building 1052: a child skeleton lying on the floor covered only by a large stone quern. Since such a practice is previously unattested in Cyprus, it was concluded that following the burial the building was abandoned and sealed (Croft, P., in Peltenburg, E.J. et al, 1988).

(d) A pithos burial. Grave 504 with a child's skeleton lying in a jar its size (Peltenburg, E.J. et al, 1985b).

(e) A possible human sacrifice (link with Khirokitia). Grave 532; tightly crouched male body with knees on chest (tied up with rope?) and a flint flake knife in front of the face (Thomas, G., in Peltenburg, E.J. et al, 1988).

(f) Finally, the encounter of chamber tombs (e.g. grave 526) in conjunction with chalcolithic pottery bears evidence that funerary architecture was well on its way to the Bronze Age (Peltenburg, E.J., 1988a). All the above attest to the great diversity of social practices on the island in the LChal, at least as depicted through the multiplicity of burial customs (Peltenburg, E.J. et al, 1985b).

Building 3 is the largest building attributed to this period (c. 8.8 meters in diameter) and it served as a central storage area for the communal(?) goods, judging by the large number of vessels excavated from its interior (Peltenburg, E.J. and Project Members, 1987). Destroyed by fire prior to the site's second phase of abandonment, it contained the body of a baby killed in the conflagration. This is also the only "event" excavated at Kissonerga (material still unpublished).

The first evidence of specialization within the society of the settlement also comes from building 3. A cache of wood cutting tools of various sizes is thought to have belonged to a craftsman (Elliott, C., in Peltenburg, E.J. and Project Members 1987).

2.4.7 Period 5 (EBA)

The presence of this period at Kissonerga has been strongly suspected since 1985 but only on the evidence of ceramic remains (Peltenburg, E.J. et al, 1985b). During the second 1990 session of excavations a standing feature and in particular, a stone basin with plaster lining in the bottom was excavated (material unpublished). Having no other evidence and in view of the abandonment of the site in LChal one could assume that this feature signifies squatter occupation rather than a permanent settlement, but the debate still remains open (Peltenburg, E., 1990, pers. comm.).

Throughout the five periods, the number of picrolite nuggets collected (especially during survey) signify that the site was a potential picrolite manufacture centre, especially in the light of the fact that this material was very popular from c. 4,000 to 2,500 BC (Peltenburg, E.J. et al, 1982).

Summarizing, the excavations at the site of Kissonerga have helped to highlight the transitional periods of Cyprus' prehistory and at the same time have provided evidence for diversity in the material culture, for cultural continuity, for foreign contacts (i.e. break of the island's isolation) and for craft specialization. In firm association with the particular site, we have archaeological testimony for the settlement's longevity and also for its storage capacity and economic surplus (building 3).

2.5 Problems of the Kissonerga Site

The first and prime problem associated with the Kissonerga site is erosion, both natural and man-induced, as has previously been mentioned. Especially after the Land Consolidation Programme was executed in the 1970's (Peltenburg, E.J. and Project Members, 1979) in the Ktima Lowlands area (where the Lemba Cluster is located) many of the shallow sites came under direct threat. Indeed, the lower field prior to the commencing of the excavation was bulldozed, and all the soil removed from its eastern part (along with the antiquities it contained) was piled up at its western side. As a result all LChal remains in the East were removed except those found in pits. The western part had to be cleared using survey methods[16] until the first unaffected level was exposed.

The second problem that Kissonerga presents is the extensive recycling of materials that took place in antiquity. According to estimates, if we assume that a chalcolithic building had a life span of roughly two or three generations (c. 100 years) prior to its final deterioration and that its destruction would create a rubble heap approximately one meter in height, then over the 2,500 years of Kissonerga's life today we should have a deposit twenty five meters in depth (Peltenburg, E.J., 1989, pers. comm.). Instead, this deposit is only 2,5 meters deep. One can easily imagine the accuracy of observation and the energy required to establish relations among contexts, and to extract sensitive information such as traces of transitional periods, from such a condensed stratigraphic sequence. On the other hand, the variety and volume of finds recovered is so great that it subsequently calls for a lengthy, tedious and systematic analysis. It is in this latter part that Geographic Information Systems can offer the means for an advanced and reliable approach to the processing of the large volumes of data that have been produced.

Chapter II - Endnotes

[1] The *Erimi Group* is a cluster of about thirty chalcolithic settlements spread out all over the island of Cyprus and was first investigated by the Cypriot archaeologist Porphyrios Dikaios in the 1930's. The main characteristics of these settlements are that they are situated close to perennial fresh water springs or rivers, on gentle slopes, for protection from the wind, or, in rare cases, in flat country. Another characteristic is that they have been constructed either right on the coast, or within a radius of 1-5 miles from it (Dikaios, P., 1936). The Lemba Cluster was not included in the original group that Dikaios published.

[2] The term ceramic denotes knowledge to construct pottery vessels while the term aceramic refers to the absence of such technology.

[3] In some references it can also be found as ECBA, i.e. Early Cypriot Bronze Age, or even EC, i.e. Early Cypriot.

[4] For more information see Hadjisavvas, S.: 1977, "The Archaeological Survey of Paphos, A Preliminary Report", in RDAC, pp 222-231.

[5] The actual area excavated is c. 1,000 m^2.

[6] The dates given are referring to the periods of Cyprus as a whole. The chronological span of the site's periods is to be established by calibrated C^{14} analysis.

[7] LAP reserves the right to formally publish any material marked "unpublished" herein. Any such material can not be reprinted, quoted or used without LAP's prior consent.

[8] The Philia period has been the cause for major debates among prehistorians. Chronologically it is placed at the margins of LChal-EBA I but it might have coexisted with LChal and developed independently in other parts of the island of Cyprus.

[9] The EBA has been subdivided into three subperiods, EBA I (c. 2300-2075 BC) EBA II (c. 2075-2000 BC) and EBA III (c. 2000-1900 BC) (Peltenburg, E.J. (ed), 1989a).

[10] The practice of placing heavy slabs on the body, chest, or even head of the deceased after it was placed

in the grave (that being shaped as in the example or just a heavy stone) is attributed to *horror mortui* (i.e. fear of the dead). It is widely believed that these stones were placed there to prevent the deceased of rising and harming the living.

[11] Skull burials, common in Cyprus and the Near East, are classified in three major categories: a) Skull separated from rest of skeleton after decomposition and buried individually in separate grave. b) Skull "artificially" separated from rest of body by a row of stones during burial practice. c) Skull separated from vertebrae after decomposition and placed standing on a stone "pedestal" in the same grave.

[12] Full information is provided in Dikaios' description on page 146 (Grave 9) and on plate 38.

[13] For more information see in Dikaios, P., 1953 the general description on page 106 (Tholos XVII, Grave II), plates XXVIa and XXVIId and the interpretation on page 340. Also, figure VI in Dikaios, P. and Stewart, J., 1962.

[14] For more information see Peltenburg, E,J., 1988b, ibid, 1988c, and Peltenburg, E.J. et al, 1988.

[15] Havara is a secondary form of soft limestone that was used as building material.

[16] Finds collected in that stage are without context and therefore useful only for statistical analyses and for drawing inferences with regard to the site's material culture.

CHAPTER III

Requirements for an Archaeological Information System for the Kissonerga Site

3.1 Introduction

The adoption of a GIS by an archaeological research project is a very ambitious process which, on one hand, offers the possibility of producing spectacular results, on the other however, presents a number of risks that may lead to an even more spectacular and disastrous economic and scientific failure. Many archaeological projects in the past have embarked on researches involving GIS that ended disastrously due to the lack of continued support, either financial or technical (e.g. see Zubrow, E.B.W., 1990a).

Ezra Zubrow (1990a, pp 185-186) argues the point that prior to any decision in adopting a GIS in archaeological work certain considerations have to be met. These are summarized below:

1) Question whether the purpose of using a GIS is for increased efficiency. If yes, then:

2) Try to identify other projects and agencies who are using GIS for the same purposes and determine whether they are willing to share information and resources.

3) Establish that the GIS you intend to use has already a reasonable market life (i.e. 2-3 years) and whether it undergoes frequent upgrading. Ensure that the vendors promptly release information regarding these upgrades and that they make them available at a minimal cost. In optimal terms these upgrades should be made automatically.

4) The greater the number of hardware platforms supporting your software the better your chances of avoiding failure due to lack of hardware support. Over-specialized GISs (i.e. those running on one machine only) may become obsolete from one year to the next.

5) In view of GIS requirements for large amounts of system resources, if your software runs on mainframe or distributed system only, ensure that access on those systems will not be hindered by other priorities given by the system's manager.

6) If one has to choose among GISs of equal quality, always choose that system which is capable of being transferred to and supported by a variety of machines. This capability may in time increase efficiency, especially when switching from a slow to a faster system.

7) Choose peripherals (digitizers, plotters, printers etc.) suitable for the size and financial capabilities of the project on which you are embarking. If given the choice, select those that offer input in a variety of ways and formats as well as those that you feel more comfortable in using.

8) Make sure that the system is efficient, protects data integrity and provides information security facilities.

9) Finally, test the use of the chosen system and start by conducting studies of limited size before embarking upon a large project.

Another major factor involved is economics but this issue will be discussed further below, in the concluding chapter.

3.2 Pilot Study (Lemba - Lakkous)

Following Zubrow's last rule, before taking up the large scale Kissonerga project, an outline version of the proposed system was tested by conducting a limited pilot study on the fairly small site of Lemba-*Lakkous*[1]. That study proved the suitability of the equipment for the project, highlighted the potential deriving from the use of such a system and indicated the possible pitfalls and limitations that might have to be faced.

Lemba-*Lakkous* being a small settlement site helped in understanding the nature of the data to be collected and the format in which it would be more suitable to record them. Meanwhile, the levels of operation on which the applications of the system were to be built and the components to be involved in each one of those levels were established.

3.3 Background to System Design

The system that evolved from the above described pilot study was named the Kissonerga Archaeological Information System (KAIS).

In order to avoid any conflict between the definitions of GIS and AIS (i.e. Archaeological Information System) it is necessary to make clear that what the term AIS implies in this context, is an accumulation of hardware and software components which operate in an integrated fashion in order to ensure a free flow of information and analytical results. Moreover, the whole system is dedicated to the storage, retrieval, and analysis of archaeologically oriented data. The fact that the particular AIS is built around a GIS does not disqualify it from being termed a system, neither does it imply that it constitutes an improvement over a GIS platform. It merely takes advantage of other software facilities not incorporated into a GIS but very important to the manipulation of data resulting from an archaeological excavation.

The main aim in developing KAIS is to provide a fully integrated GIS designed for supporting an excavation from the initial survey of the site to its final publication. Such a large scale computerized application, targeting a single excavation, has not been considered in the past (at least in the East Mediterranean region) and studies were (and still are) concentrated on limited but very specialised aspects of archaeology.

The design of KAIS is based on three principles:

a) That the primary concern in the field of Archaeology, is to process and publish the excavated data in an organised and coherent manner in the shortest time possible following the termination of the excavation process. Long-term specialised studies follow on after this aim has been achieved.

b) The majority of excavations are running on a very tight budget and any excess spending on a particular research area immediately deprives all other excavation elements from valuable economic sources.

c) Any system developed should be fully comprehensible to and readily accessible by the archaeologists (with the minimum of training) who under no circumstances should lose control of their data.

3.4 Requirements for Developing the System

In developing the present system, the following requirements were identified:

1. It was decided that only well established and thoroughly tested commercial software should be employed. During the initial research it was noticed

that there was a tendency among projects and institutions to develop their own software to fully serve their needs (Rahtz, S.P.Q., 1988). Although this is a generally valid opinion, the stand maintained by LAP was that for the sake of data transferability and compatibility among the majority of hardware available today, the Project should be ready to make limited compromises regarding the recording format of its material. Wherever that was impossible, limited modifications were made which did not significantly affect the performance of the system.

2. Although the Project had the security of the support of the Edinburgh University Department of Geography's mainframe computer, we were trying to become solely based on personal computers. This would give the excavation a feeling of mobility and independence, with the flexibility to conduct research when it was wanted, wherever it was wanted.

3. Besides the main software that the excavation wished to employ, and which is discussed in greater detail in Appendix I-A, it also proved to be necessary to use a number of secondary software packages such as statistical programmes and word processors. These packages had already been in use by LAP for several seasons and the request put forward was to try to

maintain that use and at the same time achieve a relatively high degree of software integration, thus ensuring the free flow of information through the various software components. Although this approach could lead to minor confusion, it was considered essential to employ a number of similar programmes to satisfy the variety of people who might not be familiar with a particular package and would not have the time to learn how to use it. A further requirement was to select packages which would permit data sharing by means of outputting compatible format files.

4. A powerful relational database system (RDBMS) was needed to process the bulk of the data built up during the nine years of excavation. In terms of numbers this could be translated to roughly half a million pottery sherds, 3,500 small finds, 1,600 excavated units and about 13,000 items of variable information (e.g. photographs, drawings, samples etc.). The use of a database programme ensured that the time required for the analysis of the accumulated information would be considerably less than what would be required had the research been conducted using conventional methods. Moreover, the database should provide a means for the automatic transfer of data records from other systems should that be deemed necessary.

All experts involved with the Project would receive, on request, not only lists of their finds in a tabulated form, but also a report on any relationships they had with other types of finds and/or features. To give an example, the person responsible for publishing the graves could examine whether a particular ceramic ware was exclusively associated with graves or was also encountered elsewhere, for example in the settlement. Without the use of computers such experimental queries would often be impractical because of the time factor involved.

The database was also to be linked with a GIS in order to allow the spatial recording, and eventually analysis, of the excavated units and finds. In this way, it would be possible to know not only what was found where but also the exact coordinates of its position with relation to the grid, in addition to actual geographic references (if necessary). The GIS along with the RDBMS and the interface linking them together constitute the core of KAIS (see figure 5 below).

5. In terms of database design it would be necessary to ensure that all codes in the fields involved were familiar to the specialists. As far as possible keywords already in use by the researchers should be

employed and where new ones were needed they should be proposed by the researchers themselves. Test runs would have to be carried out to ensure the functionality of the data base structure and when that was achieved each specialist would require a demonstration on how to use his/her table(s). Moreover, the director of the dig would require a full report on the design of the database structure and the architecture of each particular table followed by seminars on handling the full database.

In this way the archaeologists would be able to secure full access to the bulk of their information. For reasons of data security however, only the director would have access to the whole range of tables; the others obtaining access only to their own ones[2].

6. Another requirement of the system was to be an "open-ended" one. This meant that its components should be capable of handling a variety of information, ranging from the simplest to the most complex. Should the research requirements also change and additional software and hardware were requested, it should be possible to add these easily to the existing system. Meeting this requirement will be greatly facilitated by the efforts of the GIS software vendors to build interfaces between their different packages in an

attempt to cover the extensive range of potential GIS applications.

3.5 Designing a System to meet the Requirements

Based on the above requirements, KAIS has been designed to operate on three levels (see figure 4). The first is rescue excavations or very limited excavation seasons, where speed of data processing is most essential. The second level is at LAP's field centre where more detailed information processing can take place and research can be conducted in a limited fashion. The third, and final, level involves the installations available at the University's GIS laboratory where technological support can meet almost any requirement.

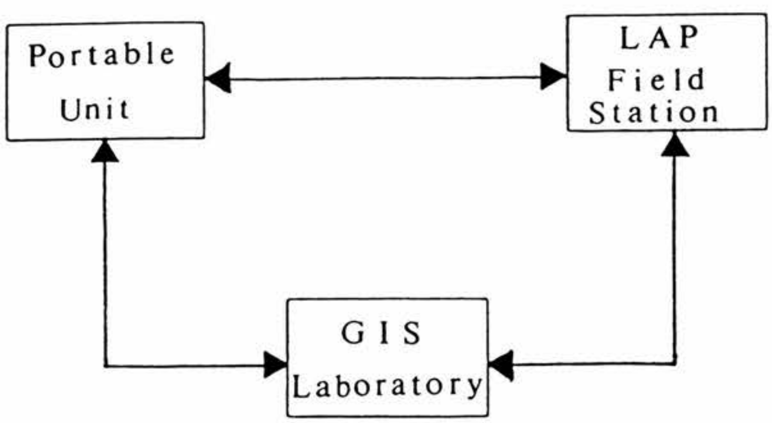


Fig. 4. KAIS levels of application and exchange of information

3.5.1 Operation Level I

Rescue excavations, as the term itself implies, involve processes of a very urgent nature. In most cases the area of archaeological interest is under immediate threat, either due to natural processes or by human development. Archaeologists are called upon to collect the maximum amount of information in the least time possible. The problem is often aggravated by a total lack of electricity supply and badly weathered transportation routes. The pressure can be partially relieved by the use of a portable computer which will ensure the safe cataloguing of the retrieved artifacts and the recording of their position in spatial terms. Limited *in situ* analysis can take place and further decisions may be made according to the results produced.

A level I application of KAIS would involve a portable computer running an RDBMS, a spreadsheet, and a wordprocessor as a minimum configuration. The database would undertake the task of recording the excavated data and the wordprocessor would enable the researchers to register their notes and initial observations directly in the field. Limited *in situ* statistical analysis would also be facilitated by an interface between the database and the spreadsheet.

3.5.2 Operation Level II

The second level would need to be implemented at the micro-computer based laboratory operating at the excavation's field centre. The laboratory would be capable of supporting extensive analyses and producing satisfactory results, providing that the analytical procedures to be followed had been established before the study season commenced. This is the only way of ensuring that all the required software has been acquired, as well as the essential hardware being leased or purchased in good time.

A level II application would involve a personal computer with a line printer as its hardware basis. In addition it would run programmes like a database integrated with a suite of other software such as spreadsheets, statistical packages and wordprocessors.

3.5.3 Operation Level III

The third level would involve the facilities provided at a fully equipped GIS laboratory. Provided there were a wide range of hardware installed to support an even wider range of software (which would be constantly updated and upgraded) and the technological advice readily at hand it could fairly confidently be maintained that the range of archaeological problems that could not be tackled at this level would be extremely limited. Another reason that would make a level III application desirabe is that GIS programmes running on mainframe computers are still far more better and efficient than their micro-computer versions.

The third level application of KAIS should have at its disposal a mainframe computer or workstation server linked to a number of graphics and conventional terminals/workstations and a variety of printers and plotters for high quality graphic outputs and printouts. Mainframe versions of the previously described software should be run, as well as a GIS.

Such a level III implementation would not only provide an efficient management of the information (through a database) and efficient statistical analyses of the data but more important, it would provide the platform for a more thorough data investigation with the addition of the spatial aspect via the use of a geographic information system.

3.6 Aims of Implementing the System

At present, KAIS is concerned with the collection and analysis of the essential archaeological data required for a well published excavation. By accelerating basic analytical operations we hope to manage to economize on financial resources and research time with the aim of providing for more experimental work. Moreover, by handing in the computerized archives to the Department of Antiquities in Cyprus, firstly the Project becomes accountable for its methods and the results produced; secondly it provides for the potential research continuation on the site of Kissonerga; and thirdly it is hoped that a good precedent would have been set for the creation of a national archive of archaeological information.

3.7 System's Potential Expansion

All the above are incorporated in version 1 of KAIS. The potential for expansion is considerable but for the forseeable future the following have been anticipated according to each level:

Level I: Perhaps a car battery operated portable computer and printer. Conventional portable computer batteries provide a power supply of about three hours of continuous use and then need approximately another three hours to be recharged. Given a situation where an excavation takes place in a remote, hardly accessible area, it would be advantageous to have the capability of increasing the amount of power supply for as long as possible.

Level II: Initially, due to the amount of data that would be loaded into the database there was no request put forward to digitize the excavation's plans during the field seasons. In the future, however, where data processing will progress along with the excavation, there will be need for digitizing facilities being available, as well as for conducting analyses of digital data. Consequently, it will be necessary to acquire the PC version of the GIS used on the mainframe, as well as obtaining a digitizing tablet and a plotter.

Level III: If KAIS is to expand to other areas of archaeological research, and most particularly into large scale surveys, simulation, and modelling, it will have to make use of a range of photogrammetric software and hardware, as well as of some advanced computer programming languages.

Indeed, besides the recording and analysis of the primary excavation data, a system like KAIS is certainly capable of expanding archaeological exploration onto various levels in both intramural and extramural areas of a site. For example, there is always the possibility of automatically conducting intra-site spatial analyses following already well documented but manual methods (e.g. Whallon, R. (Jr.), 1973; ibid, 1974; Hodder, I. and Orton, C., 1976; Hietala, H.J. et al, 1984).

With particular reference to Cyprus, where the present study is based, there are a number of possible projects, in whose development KAIS could play an important role. For instance, a modelling project could be undertaken to test the validity of Held's colonization model for Cyprus (see Held, S.O., 1990). Continuing along the same research line (i.e. modelling), site location models could be developed along Dikaios' theories for the location of chalcolithic sites (see endnote 1, p. 62; also Dikaios, P., 1936). Settlement patterns, both local (e.g. Lemba Lowlands) and general (e.g. LChal. sites), could likewise be studied. Bearing in mind that distinct regionalism was present in Cyprus, then there is a possibility for attempting to model regional interaction, or cultural expansion along the lines of the settlement shift theory discussed in chapter II (p. 48). To return to small scale studies, it would be possible to model the progressive erosion of a site in an attempt to identify how much of the information has been lost (e.g. in the heavily eroded Souskiou settlement).

Simulation is another interesting area which also has both large and small scale applications. At the large scale for example, a simulation of trade in the east Mediterranean could be conducted. At a smaller scale there is always the possibility of attempting a simulated reconstruction of the past environment of a site.

The list of research possibilities at level III is long and the methodology underlying these applications has already been well documented in the bibliography (e.g. Allen, K.M.S., Green, S.W., Zubrow, E.B.W., 1990; Rahtz, S.P.Q., 1988; Rahtz, S. and Richards, J., 1989; Ruggles, C.L.W. and Rahtz, S.P.Q., 1988; Lockyear, K. and Rahtz, S., 1991). What appears, however, to be very important in this particular study is the following.

McNett (1979) has written that archaeologists have managed to conduct cross-cultural studies based on primary material collected from ethnological projects (i.e. through the study of existing primitive societies). The results obtained and the theories developed from these ethnological researches are then projected upon the archaeological record. What is missing, however, is what McNett calls "holoarchaeological" studies; in other words, studies based solely on the information deriving directly from the archaeological record (McNett (Jr.), C.W., 1978). Through the development of the Kissonerga project, with its systematic recording methods, there appears to be a glimpse of hope that, if KAIS is sufficiently expanded, such studies could be made possible.

3.8 Problems Associated with KAIS

Figure 5 presents a schematic approach to the flow and distribution of data among the various components of KAIS. The system entails a fairly large number of interrelated software and hardware components the use of which is not always straightforward to the inexperienced user. This is the only significant problem that the use of KAIS presents.

It has been argued that although archaeologists were quick to adopt computer technology, and eventually GIS systems, in their research they are still considerably lacking in training (Harris, T.M. and Lock, G.R., 1990). However, this situation is not surprising. Archaeology has become very specialised and now every excavation needs a team of independent specialists (many of them archaeologists) to deal with

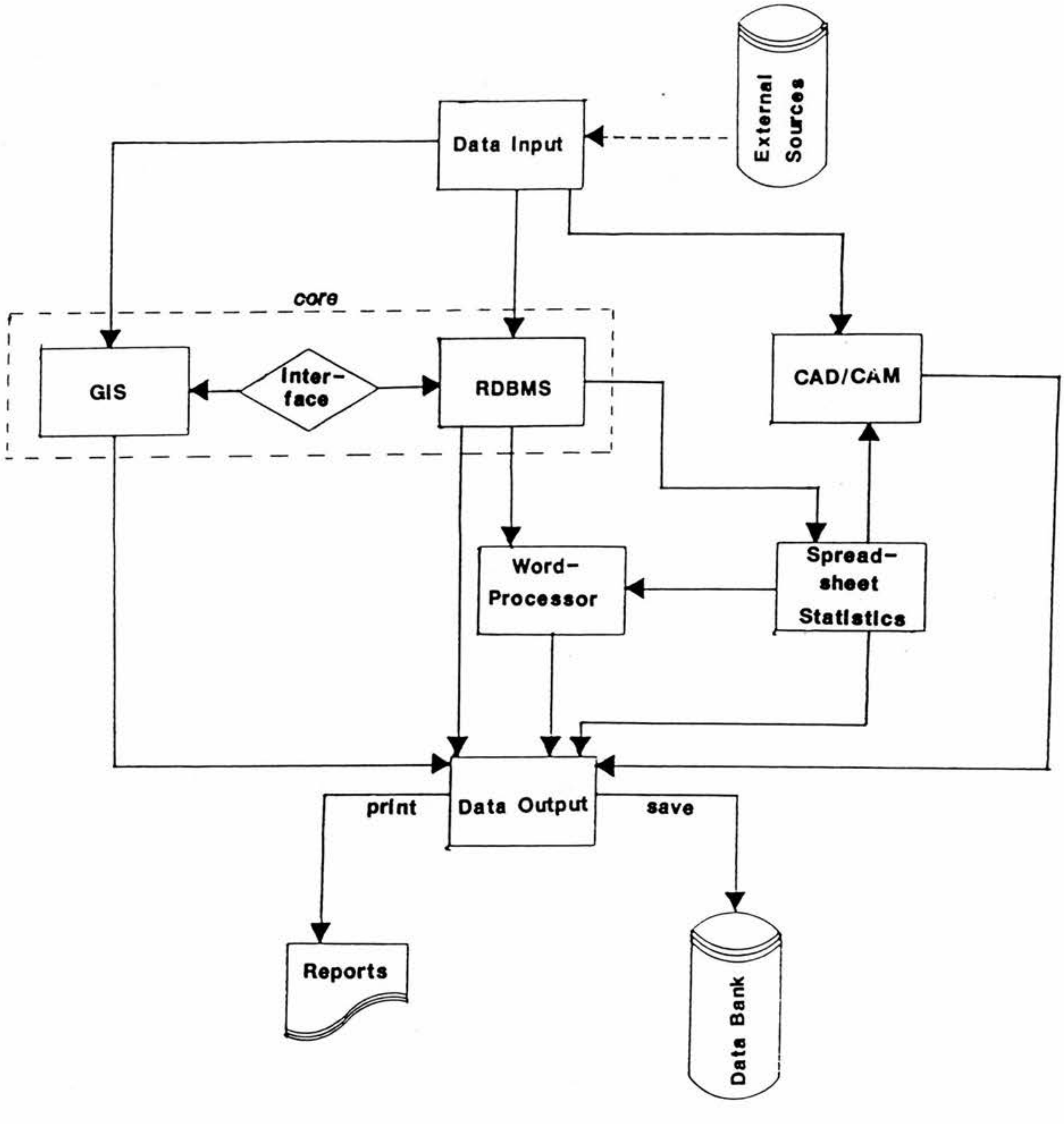


Fig. 5. KAIS - Schematic representation

the excavated material. It is possible that some archaeologists may take an interest in GIS and devote time and effort to learn their use. Nevertheless, the inevitable dilemma of having to make a choice between archaeology and computer science will have to be faced; because, like archaeology, computer science is an ever evolving field. Consequently, the chances for training a number of people involved with an excavation to the use of the full range of a system like KAIS are close to nil. Therefore, it is necessary to have a computer (GIS) specialist who will be assigned the single task of maintaining the system and expanding the areas of its application.

Having thus far introduced the excavated site and the design of a system for recording and analysis of the data derived from it, we will now proceed, in the following chapters, to explain the methodology of putting such a system to work in a large scale, multi-period and complex excavation.

Chapter III - Endnotes

[1] For full details see Papailiopoulos, D., 1988.

[2] Access was given however and information was released on request to anyone wishing to consult the stored material for research purposes.

CHAPTER IV

Implementing the System I: Database Design for the Kissonerga Excavation

4.1 Organisational Structure of the Excavation Team

Prior to embarking on the database design in detail it is necessary to examine the organisational structure adopted for management of the excavation and analysis of the data resulting from it. This provides important clues as to the types of data to be collected and the interrelationships between the data types that need to be exploited in the database design, so all of the specialists can maximize the benefit for their own area of work from access to a large structured information resource.

As already stated, there are twelve experts involved in the Kissonerga excavation. Their fields of interest are: (1) Ceramics, (2) Chipped Stone (flint), (3) Palaeobotany, (4) Palaeozoology, (5) Ground Stone Tools, (6) Wood Identifications, (7) Physical Anthropology (graves), (8) Oral Biology (dentician), (9) Pollen Analysis, (10) Metallurgy, (11) Mollusca (intertidal and land mollusca), and (12) Geomorphology.

These experts can be divided into three groups:

Group One : includes the ceramics, chipped stone, palaeobotany, palaeozoology, ground stone tools, and the metallurgy fields. The associated experts have already handed in all available data in the form of record sheets as registered at the end of each field day.

Group Two : includes the pollen analysis and the geomorphology experts who, until now, have not turned in any sort of data but who will do so in the near future.

Group Three : comprises the specialists in wood identification, physical anthropology, mollusca studies, and oral biology. These researchers will never hand in raw data but are required to submit reports concerning their findings. The director of the excavation will not personally examine any of these finds, unless he is particularly interested in any of them or his opinion is required to help resolve a particular problem of interpretation. Otherwise, the report is sufficient to provide a clear view of the particular study without involving the archaeologist in any highly specialized technicalities.

4.2 Preliminary Contacts with the Excavation Specialists

At the beginning of the design work efforts were made to contact the twelve experts well in advance, in order to discuss the form of their data, their recording methods, typical questions that they normally want to answer, desired solutions that only the use of a computer could easily provide, the sort of format that the output should have in order to be used for publication purposes, and finally, any problems that they hade which the use of a GIS could possibly assist in tackling. These efforts took the form of an introductory letter, explaining the potential of a GIS system, accompanied by sample diagrams and maps, all deriving from the material processed and the experience gained during the execution of the pilot study on Lemba-*Lakkous* (see Papailiopoulos, D., 1988). The responses to this approach varied from great enthusiasm to promises of a detailed reply at a future time, from which nothing concrete materialized. Therefore, the only alternative that remained was to personally visit the site in Cyprus with the prospect of meeting all the researchers involved (it has to be noted that almost all of the experts are based abroad for most of the time). Possible problems could then be identified with the intention of constructing an appropriate database that would handle all the archaeological information gathered.

The visit took place during the August-October 1989 excavation season. Apart from the experience gained in field archaeology, the chance arose of putting to the test a powerful micro-computer, running ORACLE PC and other utility programs. Besides some minor problems encountered at the beginning and resulting from personal inexperience in performing the duties of a "mini" system manager, no major difficulties were encountered. The hardware demonstrated a remarkable degree of resistance to the harsh conditions it was exposed to (intensive heat and high humidity levels, dust, wind and ceilings leaking during rainstorms). It never developed a fault and the software behaved fairly well.

The data that was captured on the micro-computer was related to pottery (only the 1989 season records), flotation (1986-1989 records) and small finds (1989 records). A small number of small find records from the Kissonerga-*Mylouthkia* rescue excavation (running concurrently with the Kissonerga one) were also inserted into the computer. This was initially done for temporary convenience but they will be kept stored: firstly for reasons of comparing among the finds of the two areas and secondly, for future manipulation, since much thought is being given to a formal Kissonerga-

Mylouthkia excavation in the future. A considerable amount of discussion was devoted to the automation of the human and animal bone, photographic, drawings, and unit records, all of which will be analyzed further below.

4.3 General Problems of Database Development

The general problems related to the construction of the Kissonerga database, apart from those arising from the periodic lack of expert advice on the nature of the form of data, are first of all the use of ORACLE (or rather, in fact, any other) database management software. There is the danger that a computerised data archive might cause the whole excavation to become dependent on it and, apart from the database operator, no other person involved in the excavation would be able to use it and query it. Therefore, because the computing specialist did not intend to become an "excavation technician" and involve himself in tasks such as processing and manipulating twenty five volumes of stored material, he would have to train others who would perform these operations, in order to dedicate more time to researching and developing the system rather than to its operation. Related to the latter is also the enormous volume of the data that had to be processed. Therefore, more than one person had to be trained[1] in the use of the ORACLE system. The time constraints involved were also very important since the time allowed for storing the data was equal to the duration of the excavation season.

The second problem was that part of the data, and specifically that comprising the small finds and pottery, had already been stored in a primitive form of database called PC PROMISE (see figure 6). It was worth trying to transfer these data electronically from PC PROMISE to ORACLE, otherwise time consuming manual data re-entry would have to take place. A meeting with the pottery expert resulted in the information that after the data have been transferred, updating should take place because very drastic compromising had taken place in the past due to the space limits imposed by PC PROMISE. In fact, the programme had been used as a reference index rather than a database. As a result, about seventeen categories of pottery classification had been omitted or deliberately falsely registered in order to manage to fit the pro-forma information into the file length provided by PC PROMISE. An updating of the excavation's pottery recording sheet also called for major alterations to the data structure, which would also have to be taken into consideration. A more detailed discussion on the updating of pottery records follows in the pottery database analysis.

Small Find Number 637

Class RUBBING STONE Type

Length Width 5.00 Thickness 2.60 Diameter Height

Material Basal Diameter

Stone GREY-BROWN LIMESTONE

Pottery

Multiple

Unit 310 Period 4 Master

Drawing No. Photo BW

Col

Small Find Number 638

Class POUNDER Type 2

Length 9.80 Width 5.70 Thickness 2.30 Diameter Height

Material Basal Diameter

Stone SANDSTONE

Pottery

Multiple

Unit 310 Period 4 Master

Drawing No. Photo BW

Col

Small Find Number 954

Class BEAD Type

Length 2.30 Width 0.35 Thickness Diameter Height

Material DENTALIUM SHELL Basal Diameter

Stone

Pottery

Multiple

Unit 310 Period 4 Master

Drawing No. Photo BW

Col

Fig. 6. Sample output from PC PROMISE

The above reference to the recording sheets also raises the third significant problem, which is discrepancies in the regular form in which the data should be recorded. To illustrate the problem we have to cite an example.

The recording sheets are designed for each particular excavation and for each particular category of finds, and then numerous copies of them are handed out. This means that the site supervisors are issued with a set of them at the beginning of each day and they use them for recording the individual materials that they discover. Each find category has its own recording pattern which takes the form of a sheet of paper with spaces to be filled in. Very often, the supervisor feels that he or she should deviate from the requested course of data registering in order to clarify the case more. As a result, in spaces where a single number should be registered, more than one number or even written comments are found and other times, where one particular characteristic should be recorded, two or more have been marked (see figure 7). A considerable amount of time was devoted to reviewing numerous recording sheets from each data category involved in an effort to establish the variety of these remarks and locate ways in which they could be incorporated by the database. Ignoring them was out of

Site ....km.... Year ...86 -88.

A	Unit	Period/Phase	Contam	Location	as.l.
	886	4	(Y)N/M	23231 and part of 23233	t ↑ b (43·15) 42.91

B Class 1 (General) 2 Surface (unpaved) 3 Floor (paved) 4 Basin 5 Building 6 Entrance 7 Hearth 8 Grave — Gallery? or Iwan
9 Posthole 10 Pit 11 Wall 12 Plaster & Paving 13 Stone setting 14 Stake-scape 15 Channel (groove)
16 Misc. 17 Fill of building 18 Potspread
Type ....

C Dimensions

1	2	3	4	5	6	7	8	9	10
7·50	4·50								

D Relationships

above	below	contemporary	part of
? Mud br. 500 mudbr. 947 ~~[illegible]~~ 531 1063	880, 916, 892, 915, 896	adjacent ?	

E Composition

Type	pisé ash (pisé wash) plaster sand silt clay
Colour	white black brown (reddish) grey yellow
Structure	crumb cloddy blocky prismatic laminated ash fine medium (coarse)
Consistency	loose friable (compact) hard sticky soft
Organics	charcoal (shell) (bone) roots dense medium sparse
Clarity of horizon	top sharp fair merging
	bottom (sharp) fair merging compact floor surface, reached only around basin 947
Particle Type	(stone) (cobble) pebble gravel grit sand
Sherd concentration	dense (medium) sparse none

F Artefacts

Small Finds ....T.II.... 1560 - flint object, 1563 - conical stone
1565 - ~~Basalt piece of stone~~ Biconical spindle whorl
Pottery ....

G Samples F flint, B bone & antler, S soil/stone, C carbonized seed, R C[14] assay, M mollusca

B739, F564, M522

H Plan | Section | Photo

BW Film 177 7-12
Col ....

Description (on back)

Fig. 7. Discrepancies in Unit record sheets

the question because in the majority of cases they were very important.

The fourth, and final, problem arises from that particular element that characterizes each archaeologist's research and it is called "tradition".

Every researcher involved in archaeological excavations follows certain methods and procedures that have either been taught to him or have been developed during the course of his career. The scientist is, in general terms, happy with his methodology (if he was not he would not use it) which, in turn, serves his purposes most adequately. Whether an archaeologist is prepared to deviate from this successful tradition and employ new methods, challenging the limits for accumulating new knowledge on the material he handles, greatly depends on his personal adaptability and his willingness to start learning new things. His judgement may be conditioned by the fact that most of the written material included in an archaeological publication remains unread by most people, including fellow archaeologists. What is the purpose therefore, of including detailed measurement studies on each artifact, extensive statistics, and accurate three dimensional artifact location recordings if no one will make any further use of them, unless he is extremely interested in such a study? Even then it is highly unlikely that the whole range of information will be used. To what extent should a computing specialist go in accurately recording data and insisting on being provided with precise information, if in the eyes of the archaeologist this is merely a waste of time? Should the specialist persuade archaeologists to cross that thin line between science and tradition and become totally dependent on an electronic system that will practically take control of their doings and take their data straight out of their hands? To all these questions an answer had to be found beforehand, in order to identify the extent to which an excavation should be computerized, if it is to avoid vain scientific explorations and at the same time, keep all parties involved satisfied with the results produced.

The opportunity to assess all these matters was presented at the "Publication of Excavations of Large Near Eastern Sites: The Lemba Archaeological Project Cyprus" workshop at the 1989 BANEA (British Association for Near Eastern Archaeology) conference which took place at the University of Edinburgh. The present author participated both in the workshop itself and in the peripheral discussions that followed.

The workshop was presented by the director of the excavation with the participation of the excavation's draughtsman, the statistician and the author. The main subject focussed on the form which the Kissonerga publication would take in view of the ever increasing amount of data accumulated, the possible costs of such a big publication and the potential readership. After lengthy debates, it was agreed to contemplate the idea of publishing the "synthesis"[2] in the standard book form and of transferring the data to hard disk - which, according to publishing regulations, constitutes an official form of publication (Wilcock, J.D., 1981b), presumably with the allocation of an ISBN. Queries will be answered at a pre-determined fee by retrieving the appropriate information from the database. Any degree of inconvenience resulting from such an arrangement could be resolved by the potential establishment of a central data bank in Cyprus, either at the National Museum of Cyprus, or at the Department of Antiquities in Nicosia. It is our hope that the present study may form the basis for, or at least enlighten, the development of such a data bank in the near future.

Finally, since Kissonerga is not the only excavation that has produced computerized data (e.g. Dr. Ian Todd has employed micro-computers in the processing of small finds data from the site of Kalavassos-*Tenta* -Peltenburg, E.J., 1989, pers. comm.) considerable thought had to be given to the production of a fairly standardized artifact coding system. Furthermore, the availability of systems like the French developed SOFIA (*Systeme Operant sur Fichiers Inverses en Archaeologie*), a program with scope for incorporating various databases into a single format, (le Maitre, J., 1981) should also be taken into account.

4.4 The Kissonerga Data Flow

Robert Chenhall, in his article "Computerized Data Bank Management" (see bibliography), summarizes the archaeological activities in the following diagram.

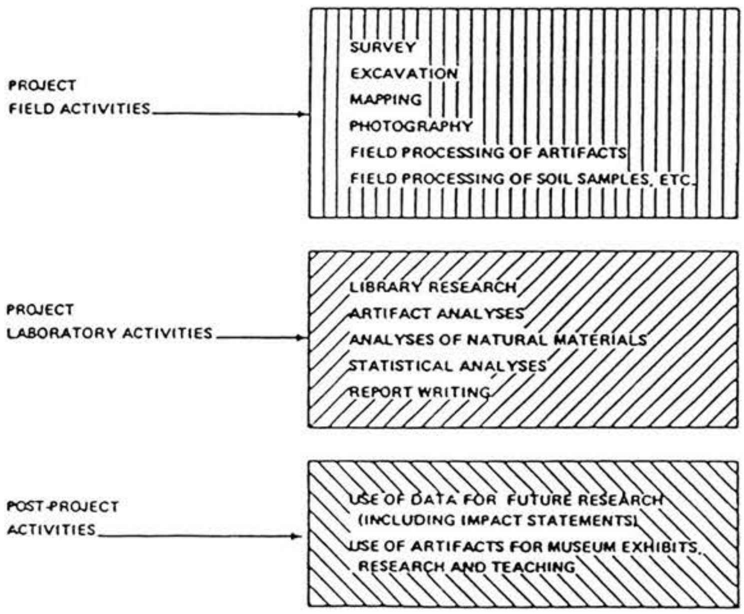


Diagram reproduced after Chenhall

In our study, however, library research and teaching entries are excluded for the moment since they would involve information that is not readily available for this excavation. Neither does information from other excavations exist - at least in computerized form- to make these options attractive.

The daily flow of data for the Kissonerga excavation is summarized in figure 8.

Excavation takes place in the field on a daily basis. During the excavation, finds are gathered separately according to the unit (i.e pit, grave, floor, trench etc.) in which they were found and to the category (e.g. bones, flints, pottery, small finds etc.) to which they belong. Soil samples for flotation are also collected in bags, and drawings of the site, sections and important units are made at large scales (e.g. 1:10, 1:20).

The day's finds are then transferred back to the field station where they are temporarily stored until the unit to which they belong has been fully excavated (i.e the unit is "closed", in archaeological terminology). Then, the specialists select their category of finds and the processing begins. During

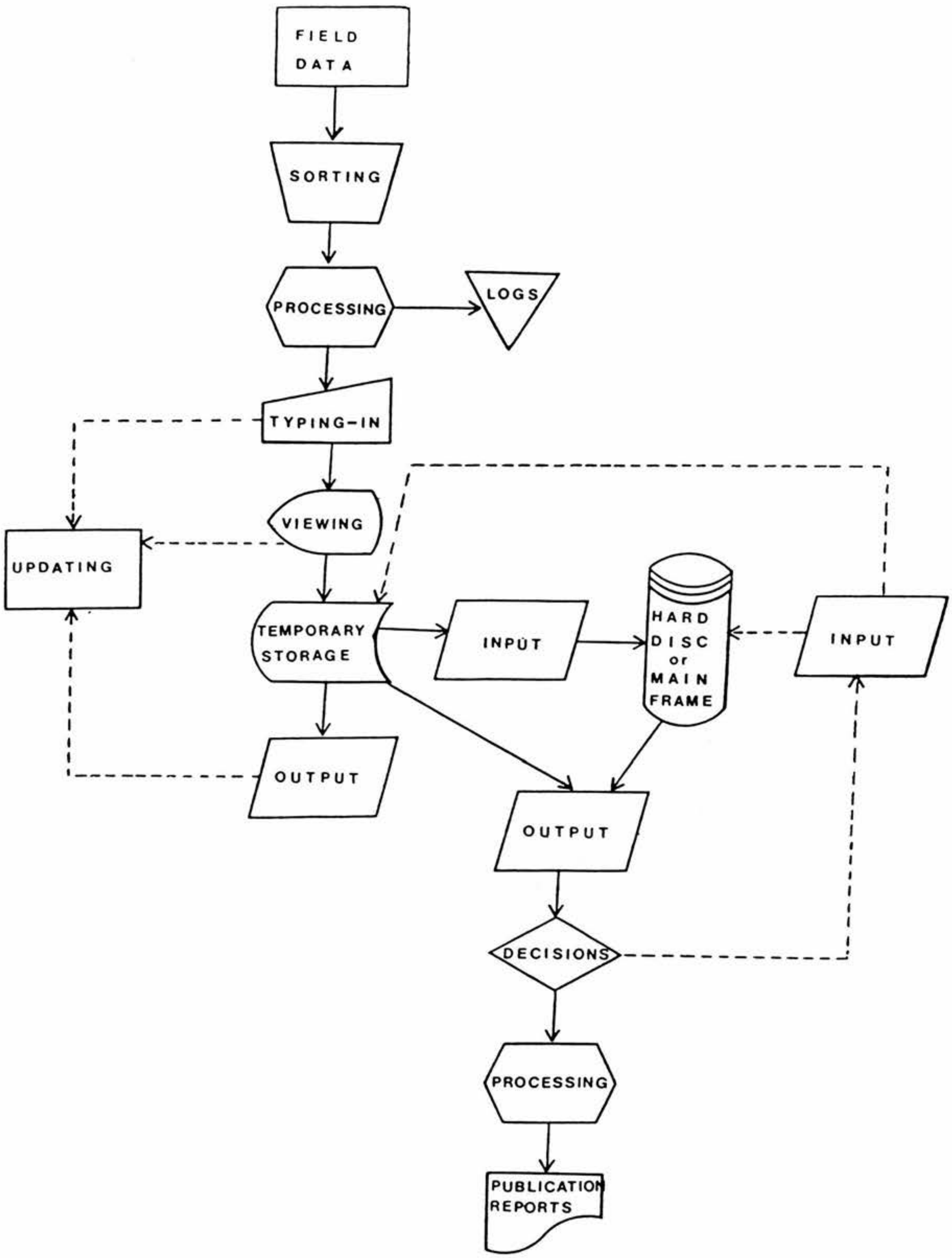


Fig. 8. Data flow of the Kissonerga excavation

this processing an initial analysis takes place and recording sheets are filled in (unit record sheets are filled in directly on the site). It is important, at this juncture, to explain these find processes since they vary according to category.

First of all, not all categories are processed at the field centre during the excavation season. Only pottery, small finds, and flotation analyses take place. The rest are left for a future period, depending on when the associated specialist will visit the site or when the appropriate laboratory will be available to conduct the analysis. Of all three categories remaining to be studied, pottery is the most important - and consequently, the most urgent to start with - since pottery is one of the main factors to date units and establish periods. Since Kissonerga is a very sensitive site (approximately 2,500 years of occupation but only 2.5 meters in depth!) the importance of pottery processing is considerably enhanced.

The sherds are kept in labelled bags until excavation is completed at the unit in which they occurred. Then they are washed, left to dry, and sorted out, firstly according to ware and afterwards by class (i.e. which part of the pot they are, as for example, rim, base, handle etc.). It is during this sorting process that the pottery record sheets are completed. At the final stage, the pottery specialist and the conservator examine the sorted sherds, correct any possible mistakes and at the end, select those pieces which bear important features and those which will be used in conservation. The rest of the sherds are disposed of through legal procedures. The reconstructed vessels are catalogued in the small finds record and handed in to the museum at the end of the season. Important sherds are drawn first and these drawings form what is called the pottery drawings record. Final analysis takes place during the study season followed by publication of the results.

The small finds are also gathered from the site in trays. Whenever it is thought important (i.e. if it is a cache, a burial or an outstanding feature) they are photographed in situ. After they have been brought back to the field station they are washed and analyzed by the specialist. The analysis involves detailed measurements being taken, identification of special features, analysis of the material they are made of, conservation if necessary - especially the metal objects - and finally, cataloguing. The excavation in itself, however, is not the only source of small finds. They may be found during flotation, or they even may turn up accidentally during other routine work as, for example, pottery washing (i.e. a pot sherd that had been used as a burnisher).

Of the three methods of conducting flotation, namely machine flotation, flotation by hand, and dry sieving, only machine flotation is passed on to the flotation record sheets. The other two methods are incorporated into the other forms of find registration. These three flotation methods are described further below in the discussion on the construction of the flotation table (see section 4.13)

The soil samples from units of interest (i.e. graves, pits, building floors or any other unit suspected of containing materials identifiable by flotation) are gathered in sacks and then transferred to the field station for processing. At least 50 litres of soil are required per unit. What is gathered in the sieves and the mesh is placed into small bags and hung to dry. The contents are then emptied into trays and separated by hand, according to initial categories. Later on they are distributed to the relevant experts. The seeds are analyzed by the flotation specialist in an effort to establish subsistence patterns.

The final analysis of all the material collected during the continuous years of excavation takes place during the so-called "study seasons". They are studied according to class, type and period to which they belong. Evolution patterns are established, correlations with other finds and units are sought and comparisons with similar material found in other excavations are made. Statistical analyses constitute a main component of this final analysis. At the end, the results are published.

In addition to artifact and unit descriptions and analyses, a "synthesis" is also compiled. By synthesis we mean the interpretation of the importance and functionality of the site as well as an attempted description of the activities that took place at the site over the periods of occupation.

Finally, the excavation is published. The archive comes as a supplement to the publication. It is self evident that the bulk of information gathered over many years of excavation work cannot all be published due to space limitations and the enormous costs involved in such an undertaking. It is also obvious that when large numbers of artifacts are gathered (e.g. flints), their analysis can take several years before it is completed and publishable. The records therefore, are kept and are available on request to the interested researcher. The artifacts are kept at the museum's storage area, awaiting analysis. The ease with which they can be located, accessed and analysed is a question whose answer relies on the nature of the records kept (i.e. the archive) and the regulations imposed by local authorities and institutions. Since the latter is entirely in the hands of people not directly associated with the excavation, all we can do is improve the quality and clarity of the former.

4.5 Database Structure and Design

Eight sets of data were thoroughly viewed, in an effort to form an understanding of the specific demands before developing a database structure. These included the general excavation area (i.e. units), pottery, small finds, the photographic log, artifact drawings, excavation plans, flotation results, and the mortuary record.

The general excavation area recording system has been drastically changed in this excavation to the form it was proposed during the GIS study for Lemba-*Lakkous*[3] (see Papailiopoulos, D., 1988). This means that a unique number has been assigned to all the structures and features of the area in which artifacts have been found, causing the database relations to become one to many (one structure includes many features) rather than many to many ones (many features, bearing the same code, are included in many different structures). Therefore, codes like B10.3 F8a which indicated building number 10, level 3, feature 8 (located within the building), and level a, which were very complicated and had to be broken down in order to be used efficiently in a database, have now become a single number, simplifying the whole process. Further simplifications have been made, as for example with the graves, which have all been assigned numbers in the 500 range (e.g. 504, 540, 597, etc.) making them easily identifiable.

In constructing the database model and tables, certain decisions had to be made regarding the form of coding to be used on various occasions during the data recording process.

Initially, the data types to be used were established as:

(a) alphabetical (character strings),

(b) quantitative, or numeric, (integers, real numbers) and

(c) BOOLEAN (presence/absence, Yes/No etc.) when an answer regarding data state had to be inserted. Boolean data has taken the form listed above as item (a).

Secondly, the question of whether to use codes or not for certain types of data was faced. In general, archaeologists prefer what is called "natural language" to codes (Wilcock, J.D., 1981a). Respecting this preference, every effort was made to provide this capability whenever possible, based on the assumption that the computer should be the servant and not the master in information handling. In some instances however, it was obvious that coding would be so much more efficient to use - as, for example, in the case of pottery items listed in the RIMCODE table (see discussion below). The main reasons for using codes were to improve the updating facility of the system and to conserve energy, time and storage space where codes could replace long strings of information that would have to be typed over and over again. Furthermore, the use of long descriptive character strings always involves the risk of a typing error and consequently, an increase in the number of checks and cross-referencing that would have been imposed on the inserted data sets.

This approach is also supported by S.W. Gaines who stated that although the human aspect should always be more important than the computer "precise definition of variables is a cornerstone of any scientific approach and the use of a computer to process the data requires a further degree of rigor in names and terminology" (Gaines, S.W., 1981b, p.87). Another convincing argument for using codes is that part of the aim of computerizing the excavation in such detail, is to make the data collected available to a variety of people, irrespective of whether they are familiar with the excavation. Data in a well understood codified form should be comprehensive to everyone, particularly if well constructed look-up tables are provided.

Concluding the discussion concerning the use of codes, the ten rules for code development, summarized by Richards and Ryan (1985, p.128), are listed. According to these rules, a code should possess the following qualities:

> 1) Uniqueness. Only one code must be applied to a given attribute state, although that state may be described in English in several ways.
>
> 2) Expansibility. The code must allow for the growth of its set of attribute states.
>
> 3) Conciseness. The code should require the smallest possible number of characters to define an attribute state.
>
> 4) Uniform size and format. The code may be more easily processed if it is of uniform size and format.
>
> 5) Simplicity. The code must be simple to apply and easily understood.
>
> 6) Versatility. The code should be easily

modified to reflect changes in artefact descriptions.

7) Sortability. The code should be easily sorted, or convertible into a form that may be sorted.

8) Stability. Codes which do not require frequent up-dating promote user efficiency.

9) Meaningfulness. As far as possible codes should be meaningful, and should reflect the characteristics of the attributes they represent.

10) Operability. The code should be adequate for present and anticipated data processing needs.

The authors go further by adding an eleventh rule, stating that only the twenty six letters of the alphabet (A-Z) and the ten digits (0-9) should be used in codes, avoiding other "decorative" forms such as asterisks, slashes etc. (Richards, J.D. and Ryan, N.S., 1985). Finally, they give the advice that one should always refer back to the coding system, no matter how familiar one feels with it, hence the presence of the code look-up tables in the present database.

The final issue to be considered, prior to the development of the data model, concerned the amount of archaeological information to be held by the database. The primary assumption was that knowing when to use the computer is as crucial and important as knowing when not to use it. Therefore, available data sets such as mollusca, sections, anthropological and animal bone were initially deliberately excluded. It was considered best to study them separately from all other sets, identify the implications involved and the treatment of the data required, and not hastily attempt to incorporate them into the database at this stage. The main reason behind this decision was that since the publication deadline is drawing closer and results have to be produced in order to prove the functionality of the method followed, unclear sets of information that would take a considerable amount of time to be studied (35,000 records exist for animal bones alone) should be, for the time being, omitted. Instead, conventional "by-hand" analysis will be undertaken for these datasets.

4.6 Justification of the Database Structure

Let us adopt a step by step approach to the development of the database structure in order to list all the processes involved and explain some of the terminology in use.

First of all, Howe (1983, p. 37) has summarized four rules referring to the creation of tables within the database. These are:

1) There is no significance associated with

the ordering of rows within a table. Rows can be interchanged without affecting the information contained in a table.

2) The order of the columns in a table is also not significant but each column should have a distinct attribute type name.

3) The use of multiple values is not allowed.

4) Each row must be distinct by ensuring that no two rows bear the same values throughout.

The database tables that comply with the rules listed above are called normalised tables.

The definitions for the terms entity, attribute, relationship, relation, and primary key are as follows:

"Entity is a person or thing which exists in the real world and which possesses characteristics in which we are interested" (Oxborrow, E., 1986, p.25)

"Attribute is a quality, feature or characteristic of an entity" (Oxborrow, E., 1986, p.25).

"Relationship is an association between two (or more) entities" (Howe, D.R., 1983, p.94).

"Relation is a named object together with its associated attributes" (Oxborrow, E., 1986, p. 38).

"Primary key of the relation is one or more attributes of the relation which enable record occurences in the relation to be uniquely identified" (Oxborrow, E., 1986, p.38).

There are three types of entity relationships the definitions of which will be given with the aid of archaeological examples:

(a) 1:1 (i.e. one:one): Consider the situation where there is only one drawing made for each small find, and each small find is depicted on only one drawing.

(b) 1:N (i.e. 1:many): For example, there are many small finds located in one unit but each small find can be located in only one unit.

(c) N:M (i.e. many:many): There may be many photographs taken from one unit and many units may be incorporated in one photograph.

The database structure diagram is presented in figure 9. During the process of designing the structure the following assumptions were made:

Twelve entities are present in the Kissonerga database. These are the units, the pottery assemblages, the small finds, the small find drawings, the unit drawings, the film records, the site's chronological periods, the locations of the units, the flotation samples, the graves, the burial chambers, and the burials.

Studying the relationships between these entities the following were observed:

a) There are six many:many relationships present, those between SMALL and FILM, between UNIT_LOG and FILM

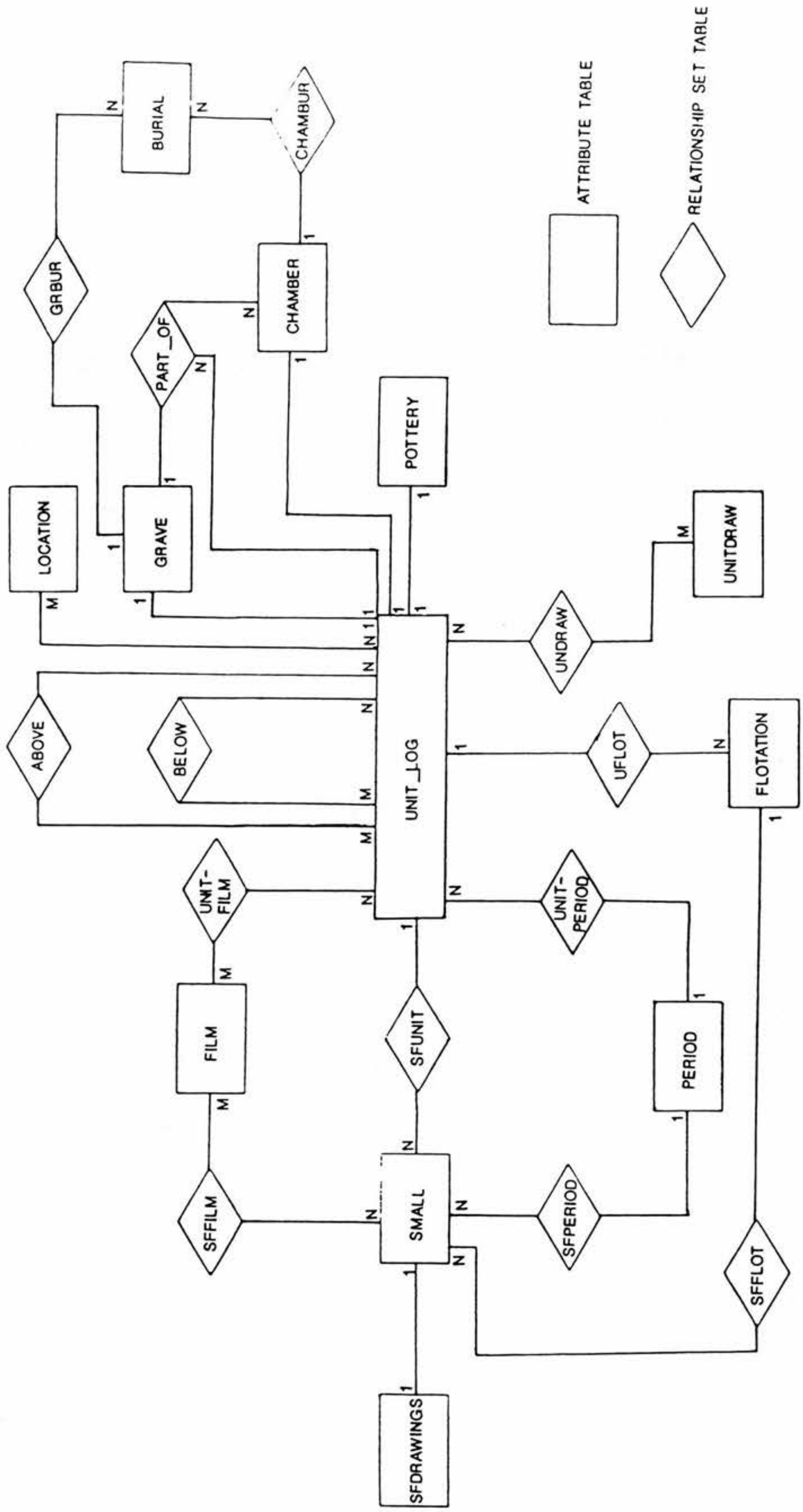


Fig.9. The Kissonerga database structure

(because generally, small find and unit pictures are recorded on both black and white, and colour films), and UNIT_LOG with each one of tables ABOVE, BELOW, LOCATION and UNITDRAW.

b) There are four 1:1 relationships - those between the SMALL table and the SFDRAWINGS table, UNIT_LOG and POTTERY, UNIT_LOG and GRAVE, and, UNIT_LOG and CHAMBER.

c) There are nine 1:N relations - those between UNIT_LOG and SMALL, UNIT_LOG and FLOTATION, PERIOD and SMALL, PERIOD and UNIT_LOG, FLOTATION and SMALL, UNIT_LOG and PART_OF, GRAVE and BURIAL, CHAMBER and BURIAL, and finally, GRAVE and CHAMBER.

The rules determining the structuring of tables to represent many:many relationships, as stated by Howe (1983, p. 132) are that:

> 1) Regardless of membership class, define three table types, one for each entity and one for the relationship.
>
> 2) If there is one relationship between N entity types, define N entity table types and one relationship table type.

Quoting Howe (1983, p. 129) there are three rules governing the construction of a 1:1 relationship:

> 1) If membership is obligatory for both

entity types, put all attributes into a single table type.

2) If membership is obligatory for only one entity type, define two table types, one for each entity. Post the identifier of the non-obligatory entity into the obligatory entity's table type.

3) If membership is non-obligatory for both entity types, define three table types, one for each entity and one for the relationship.

In our case, all 1:1 relationships present fall under rule number two. In the case of small finds and drawings, not all small finds have a drawing made of them but each drawing number is associated with a small find. Consequently, the small find number will be included in the SFDRAWINGS table. The situation is similar for the rest of the tables involved in this category.

Again according to Howe (1983, p.132) the rules governing 1:many relationships are that:

1) If membership of the "many" entity type is obligatory, define two table types, one for each entity. Post the identifier of the "1" entity into the "many" entity's table type.

2) If membership of the "many" entity type is non-obligatory, define three table types, one for each entity and one for the relationship.

The second rule is the case between all of the 1:many relationships in the present database structure.

It is not certain that all units will produce small finds, while samples for flotation have been collected only from certain units and not from all units present. Flotation samples only rarely produce small finds, not all units and finds are identified with a particular period - at least until the final study of the excavated material - graves may have no chambers, and finally, both graves and chambers may not contain any burials whatsoever. As a result, "third" tables have been created to establish the relationship between the main tables.

Below is a summary of the relational properties associated with the database tables:

Table 1 - Summary of table associations

1. **UNIT_LOG ---> SMALL** = 1:N; N entity type non-obligatory; 3rd table required.
2. **UNIT_LOG ---> FILM** = N:M; 3rd table required.
3. **UNIT_LOG ---> POTTERY** = 1:1; Pottery non-obligatory; two tables required.
4. **UNIT_LOG ---> FLOTATION** = 1:N; N entity type non-obligatory; 3rd table required.
5. **SMALL ---> FILM** = N:M; 3rd table required.
6. **SMALL ---> SFDRAWINGS** = 1:1; Small finds entity type non-obligatory. Two tables required.

Table 1 (cont'd)

7. **FLOTATION ----> SMALL** = 1:N; N entity type non-obligatory; 3rd table required.

8. **PERIOD ---> SMALL** = 1:N; N entity type non-obligatory; 3rd table required.

9. **PERIOD ---> UNIT_LOG** = 1:N;N entity type non-obligatory; 3rd table required.

10. **UNIT_LOG ---> UNITDRAW** = N:M; 3rd table required.

11. **UNIT_LOG ---> GRAVE** = 1:1; Grave entity non-obligatory; two tables required.

12. **UNIT_LOG ---> CHAMBER** = 1:1; Chamber entity non-obligatory; two tables required.

13. **UNIT_LOG ---> *PART_OF*** = 1:N; Part_of entity type non-obligatory; 3rd table required.

14. **GRAVE ---> BURIAL** = 1:N; Burial entity type non-obligatory; 3rd table required.

15. **CHAMBER ---> BURIAL** = 1:N; Burial entity type non-obligatory; 3rd table required

16. **GRAVE ---> CHAMBER** = 1:N; Chamber entity type non-obligatory; 3rd table required.

17. **UNIT_LOG ---> LOCATION** = N:M; 3rd table required.

18. **UNIT_LOG ---> *ABOVE*** = N:M; 3rd table required.

19. **UNIT_LOG ---> *BELOW*** = N:M; 3rd table required.

4.7 The UNIT_LOG

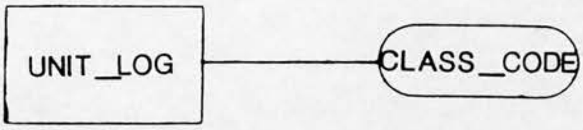


Figure 10 shows a sample unit log sheet. The unit log constitutes a comprehensive and more accurate summary of the unit sheet which contains very detailed but often redundant information which, in addition, is subject to frequent modifications.

One entity table and four relationship set ones have been constructed to accommodate the data associated with the archaeological units of the excavation. Table UNIT_LOG, the main table, contains the following attributes:

a) <u>Unit</u> (the address number of each individual unit),
b) <u>Classcode</u> (the code defining the nature of a unit, e.g. grave, building etc.),
c) <u>Classcom</u> (any particular comments regarding the unit),
d) <u>Status</u> (stating whether a unit has been disturbed, is undisturbed or in a mixed condition), and
e) <u>Period</u> - which is a temporary entry until table

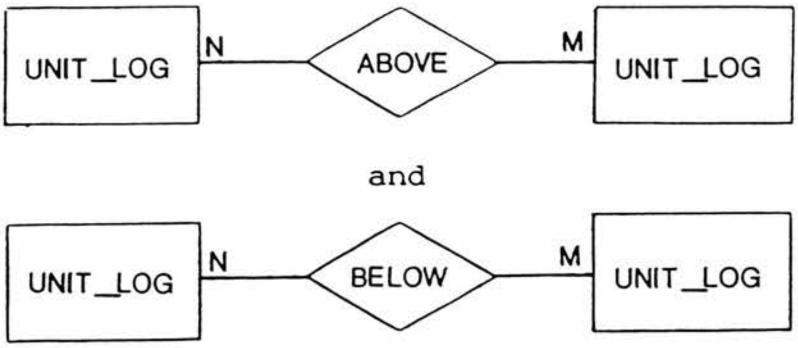
LAP 1988

Unit	Description	Square	Status	Pot	Period
1032	Pit in surface 803 below 204	21.23.1	M	Grey	4
1033	Basin in General 866	23.23.3		Grey	3/4?
1034	Wall on 886	23.23.1		white	?
1035	General below 803	21.23.1	M	Grey	4
1036	Basal fill of pit 913	21.24.2		Grey	4
1037	General of H3	23.23.3		Grey	4
1038	East chamber of pit 913	21.24.2		White	4
1039	Pit in 815	20.23.4/	M	Grey	4
1040	Pit in 150 above wall	20.24.3	M	Grey	4
1041	Hearth in 1044	20.24.3	OK	White	4
1042	Rubble above 7	19.25.3	M	Grey	4
1043	Furrow cuts 1035	21.23.3	Lss	Grey	4?
1044	Building sealed by 150	20.24.3		White	4
1045	Wall of 1044	20.24.3	OK	White	4
1046	Building abutted by 1044	20.24.3		White	4
1047	Wall of 1046	20.24.3		White	4
1048	Fill of 1046	20.24.3		White	4
1049	Surface below 1035	21.23.1	M	White	4
1050	Pit in 1049	21.23.1	OK	White	4
1051	Pit in 1049	21.23.1	M	White	4
1052	Building with wall 975	20.23.4		White	4
1053	Fill of building 1044	20.23.4			4
1054	Fill of building 1052	20.23.4	M	White	4
1055	Posthole in 944	21.24.2		White	4

Fig. 10. Sample of a unit log sheet

PERIOD is finally filled in (see section 4.14).

In archaeological stratigraphic terms, a unit can be above or below several other units attributed to a variety of chronological periods. Therefore, "reflexive" relationship set tables (i.e. associating an entity table with itself) were introduced to record this type of information. To further explain the latter, the structure normally would have been:



It is evident that table UNIT_LOG would have to be used twice to provide practically the same type of information as if it had been used only once. Therefore, the second UNIT_LOG entity table has been cancelled.

The case of the PART_OF table is identical. Very often a group of smaller units is attributed to a larger, main one. For example, units such as a <u>hearth</u>, a <u>wall</u>, a <u>floor</u> and an <u>entrance</u> would be part of a <u>building</u>. The actual structure would have been:

and for the reasons stated before the second UNIT_LOG entity table has been omitted[4].

The case with the LOCATION relationship set table is similar but in this case we must explain some of the theory involved.

The terms "location", "context"[5] and "provenance" are all well established in the archaeological literature as referring to the relative position of an excavated unit in relation to the excavation grid and quadrants established prior to the commencement of the digging process.

With the aid of figure 11 we will try to define the terms "grid" and "quadrant". A grid is a series of arbitrary squares of standard size which varies for each excavation (see fig. 10a). At Kissonerga the size has been established at 10 X 10 metres. Each grid square is subdivided into four quadrants, leaving in between a sort of cross-shaped wall called the "baulk" (see fig. 10b). The faces of the baulk are called "sections". Thus, a reference 22.23.4, for example, means that the unit is located in square 22 longitudinally, 23 latitudinally, in quadrant number 4.

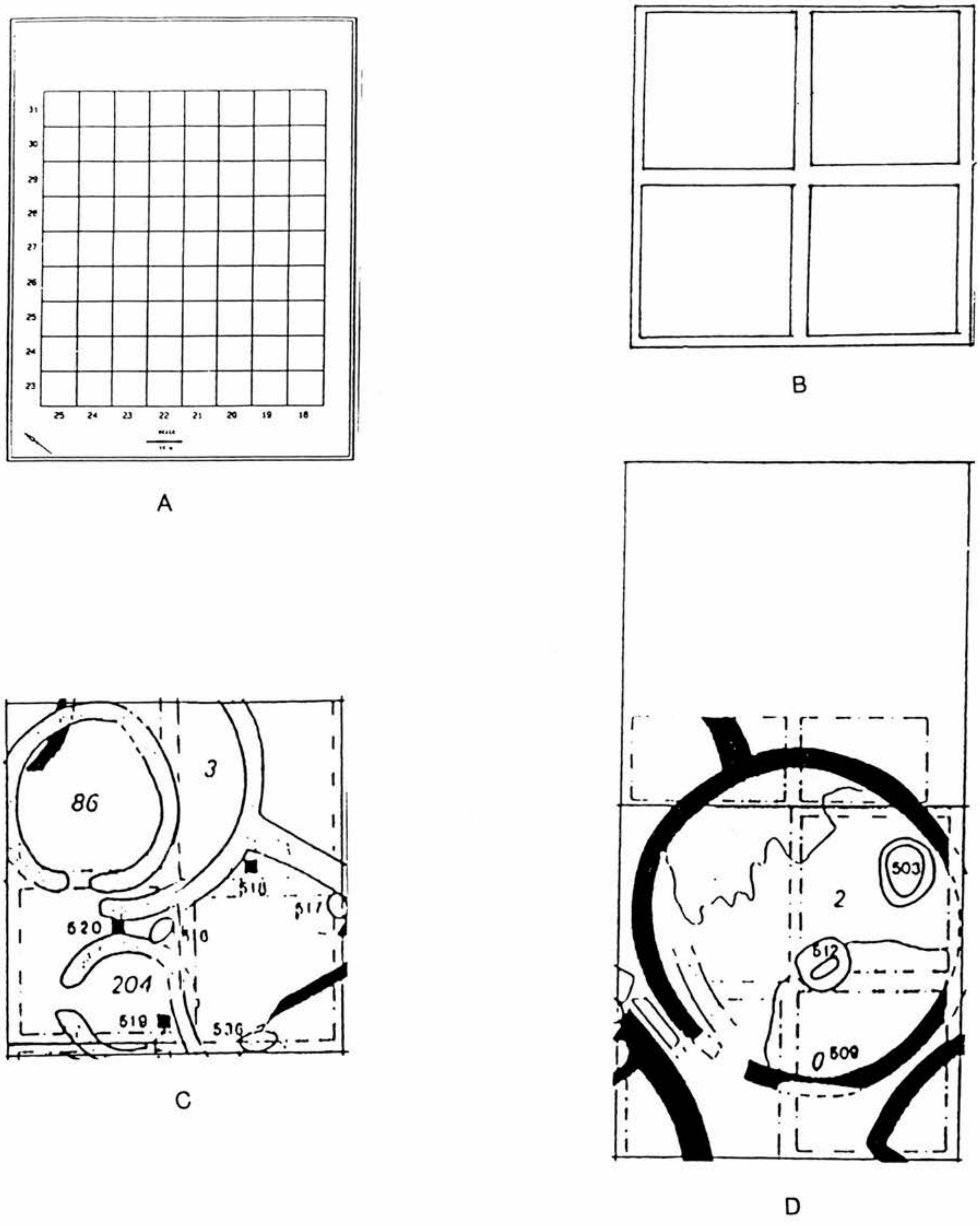


Fig. 11. Grid squares and quadrants

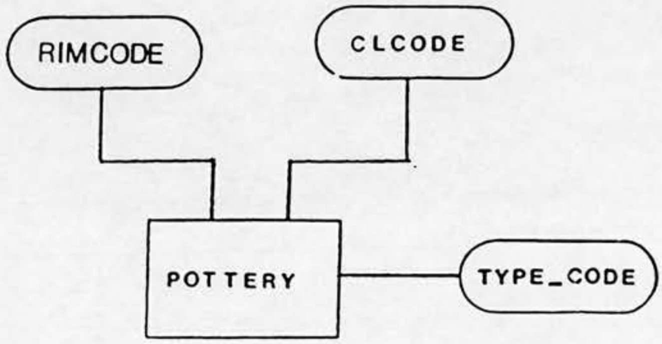
Very often we have a single unit, as for example a wall, extending through more than one quadrants in the same grid square (see plate 10c). In this case its reference would be 22.23.2-3 (referring to wall of building 3). In other cases a wall could be running through two grid squares diagonally and through more than one quadrant in each square (see plate 10d). In such a case the reference would be 22.23.1-4 - 22.24.3-4 (referring to wall of building 2).

If we were to record the true geographic coordinates of each grid square and each quadrant within these squares, our structure would involve at least two entity tables and a relationship set one (since it is a many:many relation). The structure would therefore be as follows:

Since what we actually record is however only the archaeological location (e.g. 22.23.1) without the true geographical references to which it corresponds, LOCATION could become a pseudo-relationship set table containing entries such as Unit and Location only.

The look-up table called UNIT_CLASS_CODE associated with table UNIT_LOG will contain entries such as Classcode and Class.

4.8 Pottery



A sample of the pottery recording sheet is illustrated in figure 12. The pottery data is located in one main table named POTTERY, and two look-up tables - the RIMCODE and the CLCODE.

In relation to the construction of the POTTERY table, the first decision made was that the primary key should be Class, namely whether it is about rims, handles, bases, spouts, open or closed body vessels, or part of an unclassified body of a vessel. This approach was taken mainly because each sherd or a number of sherds do not bear a distinct classification number - as is the case with other artifacts - but they are rather attributed the number of the unit in which they are found. Attention must be drawn to the fact that the

KM Pottery Processing Date HM88 Grid Ref A.24.1 Unit 310 Period ______ /

Total sherd count this unit 237 Drawing Nos. ______ RW sand for LM

Initials DM/DB Photo Nos. ______

RIMS	Cb	PCb	RWLM	GBW	RWEC	RMP	BTW	RWMC	"X"	RWMC	RBSB	SW	CPW	CH	?	TOTAL
1. PLATTER																
2. [illegible] BOWL										1						2
3. DEEP BOWL										6						5
4. TRAY														*1		1
5. HOLEMOUTH											1					1
6. HOLEMOUTH STORE JAR									1	1						2
7. FLASK										1						1
8. GOBLET																
9. OVOID BOWL																
10. CONICAL BOWL																
11. [illegible]																
12. SPOUT BOTTLE																
13. KYLIX																
14. PELLIA JUG																
15. PELLIA JAR																
16. PELLIA JUGLET																
17. SPOUT BOWL																
18. SPOUT HOLEMOUTH																
19. BAGGY HOLEMOUTH																
20. SMALL COLLARED JAR																
21. TRIANGULAR BOWL																
22. GLOBULAR BOWL																
23. COLLARED STORE JAR																
24. BUCKET																
25. BARREL																
26. BASIN																
27. HOUSE MODEL																
28. ???? RIM						2			2	10						14
TOTAL						2			3	19	1			1	0	26
HANDLES			1			0			0	0	0			0	0	0
BASES						0			0	3-B, 1-D, 2-C, 1-?	0			0	0	7
SPOUTS		1				0			0	0	0			0	0	0
? BODY •						12			12	90	10			10	10.	144
? BODY •						2			1	48	3			0	6	60
? BODY ?																
GRAND TOTAL						16			16	164	14			11	16	237

Fig. 12. Sample pottery record sheet

discussion here concerns only sherds. Whole pots or those who have been reconstructed (in whole or in part) bear a small find number and are listed in the small finds registry.

A Rimcode is assigned only to rims. There are twenty eight types of vessels identified so far and consequently, twenty eight types of rims.

The body classes bear a Clcode (class code) which subdivides them into various categories. Unfortunately, the full descriptions of the categories have not yet been made available by the pottery specialist, justifying therefore the absence of a CLCODE look-up table. This table may be added to the structure in the near future or it may be omitted altogether if a set of drawings is alternatively chosen to be used as reference.

Fifteen types of ceramic ware have been identified as well and their reference is in code form[6]. These codes are fairly standardized in Cypriot archaeology and are easily distinguished by the ceramic experts. A personal opinion is that a third look-up table - namely, TYPE_CODE - should be added, decoding the ceramic ware types for use by researchers foreign to the archaeology of Cyprus and its associated typology.

Finally, inclusion of the Period, Date, Initials and Total columns that appear on the recording sheet was avoided. Period was omitted due to the database structure rules previously listed in the discussion of the structure diagram. The Date of processing of the sherds and the initials of the person who processed them have no significance in relation to the permanent storage of the data in an excavation database. Their presence is only temporarily important and could be confined to the recording sheets only. Totals were also left out because the number of the sherds under each particular type of ceramic ware is frequently updated during the initial stages of the sorting process. Since ORACLE provides a facility for calculating totals, this can be done accurately at any future stage.

There are two possible approaches to the structure of the pottery table. The first, and most complicated, is the following:

Unit, Class, KM (year of excavation), Provenance (exact location; not always recorded), Rimcode, Clcode, Cb... etc. (list of all ceramic ware types), Diameter1-5[7].

It is evident that the format of this table is not very flexible since a number of null values will be incorporated in every row of attributes. Also it does not follow the rules of normalization. It has to be considered however, that the presence of certain types of vessels and wares is as important as their absence, especially when it comes to drawing any conclusions based on the study of pottery finds. This is particularly true for studies which involve statistical analyses. Therefore, null values in the pottery table should simply be considered as another form of data.

A second alternative for the structure of the pottery table is the following (also see table POTTERY in Appendix I-B):

Unit, Class (e.g. rim, base etc), Ware (i.e. ceramic ware type), Sherdnum (number of sherds of particular class and ware), KM, Rimcode, Clcode, Diameter1-5.

This structure saves space giving the table depth instead of width but the absence of certain ware types cannot be identified at first glance. After a query has been executed, the resulting ceramic types have to be counted in order to locate the missing ones.

Nevertheless, the advantage of this approach is evident in the recording of various diameters measured or predicted during the study of the sherds. On the original recording sheets an asterisk, placed beside the number of pottery sherds of a particular class and type of ware, marks the presence of recorded diameter measurements with no specific reference however to the exact sherd measured. On the back of the sheet a special note records these measurements which may be more than one for each particular category. For the purpose of passing this information to the computer a hierarchical method was adopted, assigning several diameter slots (i.e. DIAMETER1, DIAMETER2 etc.) for data input.

By following the first table structure proposed the researcher should always refer to the original recording sheets to identify wares marked with an asterisk. With the second structure, although it makes data recording a more tedious process, no such cross-referencing is required since only one particular ware is registered per record. It was this second table structure that was finally adopted by the Kissonerga database.

With reference to the updating of the old recording pottery sheets, a concordance was issued by the associated specialist in order to assist data corrections of the material transferred from PC PROMISE to ORACLE. This concordance is summarized below and refers to the RIMCODES listed under CLASS "rim":

Table 2 - Pottery type corrections

RIM

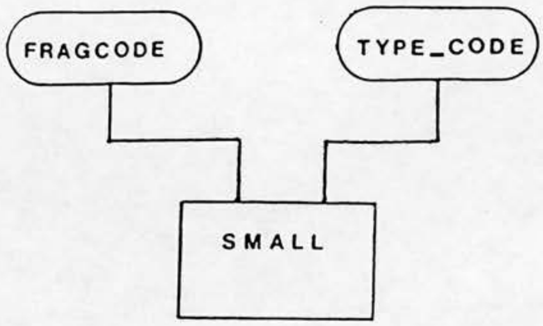
Old Sheet Number	New Number
1	1
2	2
2/3	9
3	3
4	4
5	5
6	6
7	7
8	deleted
9	deleted
10	deleted
11 or 20	28
12	12
13	13
14	14
15	15

Type 3, the old "bucket" is now referred to as "deep bowl" and <u>bucket</u> in new typology is "a large vessel with convex sides" (No. 24). Also, TYPE "RPV" is now recorded as "Unknown" (unless stated otherwise). Moreover, due to ORACLE limitations TYPES ""X"" and "RW?" are recorded as "X" and "RW_UNK" respectively[8]. CLASSES "?BODY o" and "?BODY o" have been updated to "open body" and "closed body".

Provenance - alias grid reference - although not included in the new recording sheet, is kept since it might be useful in the analysis of older material, although no clear reason was given for its maintenance. If the analysis of the materials proves this information to be of no significant importance, it can be deleted from the final structure.

The exact date of the processing of the material has been replaced by a two digit number (e.g. 88, 89 etc.) and prefixed by the initials "KM" (i.e. Kissonerga-*Mosphilia*). The number refers to the year in which the sherds were found for reasons of locating them if the need arises. This could occur if they are needed for conservation purposes, or if they have to be taken out from the museum storage area, where they are stored according to the year of excavation, for further study (the latter refers only to those pieces of pottery which have been handed in to the museum[9]). Both the number and the prefix "KM" fall within the finds recording specifications issued by the Department of Antiquities of the Republic of Cyprus and which are compulsory for all excavations taking place on the island.

4.9 Small Finds



A sample of the small finds recording sheet is illustrated in figure 13. The small finds data is located in one main table named SMALL, one relationship set table, associating small finds with the units in which they were excavated, one look-up table - which can later be split in several ones (e.g. one for axes, one for adzes etc.) - recording small finds typology and their definitions, another look-up table defining the fragment codes and finally, a second relationship set table relating the small finds with the periods to which they belong. A further relationship set table has been created, relating small finds to photographs.

The primary key in the SMALL table is the Sfnumber (i.e. small find number) which is unique[10] for each artifact. Small finds have been numbered sequentially as they turned up during the excavation process. The

SF Number 2399

Context 1480
20.24.1

CLASS polisher fragment TYPE 1

MATERIAL diabase ✓

DIMENSIONS

1	2	3	4	5
4.5 (frag)	2.8	2.0		

DESCRIPTION

From from a larger tool with oval section, convex faces pecked finely all over except at preserved end which has flat ground polished facet + fine lines clearly visible. Smaller polished facet on side forms sharp edge with

Not a chisel fragment.

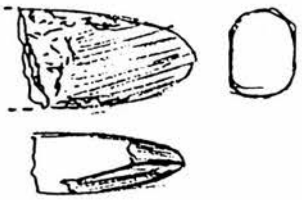


PHOTO NO B267/5-6

DRAWING NO

DATE 27.9.89

Fig. 13. Sample small find recording sheet

columns which constitute the SMALL table are the Sfnumber (small find number), Class (whether it is an axe, an adze etc.), the Type of the artifact in character code form, the Material of which the artifact is made of, its Leng(th), Width, Thickness and Height, two diameters (Diameter and Basal) - the former denoting measurement taken at the rim of a vessel and the latter at its base -, and finally, a Frag(ment) alphabetical code based on the initials of the missing dimension (e.g. L, W, TH, etc.).

Originally it was noticed that entry Type could take two forms, either an alphanumeric or a numeric one. The reasoning behind the two types of code is that in the original records the typology among classes of artifacts is very similar. Thus, for example, one can have an adze of type 2 as well as an axe of the same type code (i.e. 2). On the other hand, the definition of this type is very different from class to class of artifact. Therefore, if we are to adopt only one single look-up table to record the small find typology, an alphanumeric code has to be used (e.g. axe2, or ax2 etc.). Contrary to this argument, if several type_code look-up tables are implemented in the database structure (e.g. adze_type_code table), a single numeric code could still be used in the main table[11]. The disadvantage of the first option is that one has to remember the codes in use, or there may be need for another look-up table listing the options. The disadvantage of the second method is that typology can be used only for reference and not as the basis for a query to be executed. It will also occupy more database space by creating several secondary look-up tables.

Sometimes an artifact is identified as having multiple uses. Thus, for example, we have classes like rubbing stone/cupped stone, denoting that the artifact was used as a rubbing stone as well as a cupped stone either concurrently or after its initial use had seized. Often a type code follows this recording in the TYPE column. The small find specialists immediately associated with the particular excavation, can easily identify to which of the two uses the code refers, but someone not so familiar with the practices of the excavation may have problems associating the artifact with the typology provided. Therefore, it was judged as essential to create two records (one for each use) for the same artifact and to attach the typology to the one to which it really belongs. Moreover, with this method, when the study of individual classes of artifacts takes place the ones with multiple uses will be used twice (e.g. in this case a query will classify the small find once as a rubbing stone and once as a cupped stone).

It was originally thought that the attribute Material could not be used as the basis for a query since the descriptions provided in the record sheets are far from standardized. This was mainly due to the great variety of materials that were used in the construction of the artifacts. Its role therefore would have been limited to reference only. However, after careful consideration, we managed to isolate certain descriptions of materials that could become fairly standard. Consequently, another attribute column was added to the table titled Materialcom (i.e. material_comments) which includes all subsidiary information regarding the nature of each particular material listed. A similar procedure was followed for the attribute Class where all those classes occurring frequently were standardized and the secondary descriptions were placed in a column called Classcom (i.e. class_comments). There was nothing that could be done either for class names or materials that were unique or did not occur very frequently. The only way that these cases can be retrieved is by a process of elimination, that is if the query is of the form: "select * from small where class is not a, b, or c"[12].

4.10 Small Find Drawings

A sample of a small find drawings sheet is presented in figure 14. The drawings data has been placed in the SFDRAWINGS (i.e small find drawings) table. It was not possible to have one table for all drawings made during the excavation. There is an enormous variety incorporating small finds, pottery sherds, units, sections and many other elements, including their associated information, which varies from category to category. Therefore, each major category of features has its associated drawings table. The same applies for the photographic record, but this is a matter that will be discussed in a later section (section 4.12).

The main table contains all the information present in the original record sheet, namely the Drnumber, the Scale at which it was drawn and the small find number (i.e. Sfnumber) drawn. The column marked "Initials" was omitted since it was supposed to contain the initials of the draughtsman who executed the drawing, but its use was modified to contain the type of graphic equipment that was used in the drawing process. Since that was "pencil" in all cases there was no need to repeat it indefinitely.

Catalogue type Drawing SF   Number ....1..............

Number	Description	Context	(A)	Initials
1	pottery spindle whorl	KH 573	1:1	
2	stone figurine	KH 578	"	
3	chert pendant	KH 580	"	
4	pot lid RHP	KH 585	"	
5	chisel (type 2)	KH 591	"	pencil
6	picrolite pendant	KH 592	"	
7	antler frag	KH 594.	"	
8	stamp seal	KH 597.	"	
9	stone phallus	KH 623.	"	
10	pot disc (multi perf)	KH 628	"	
11	pestle	KH 631	"	pencil
12	worked shell	KH 653	"	
13	"	KH 654	"	
14	fig frag (foot/head)	KH 670	"	
15	" (head)	KH 671	"	
16	" (torso)	KH 672	"	
17	stone dish	KH 680	"	
18	burnisher	KH 681	"	
19	bead frag	KH 686	"	pencil
20	cupped stone	KH 693	"	
21	copper chisel	KH 694	"	
22	conical stone	KH 695.	"	
23	grooved "	KH 705	"	
24	cupped stone	KH 725	"	
25	bone point	KH 743	"	

(A) Scale. ~~Feature type~~

Fig. 14. Sample small find drawings record

4.11 Unit Plans

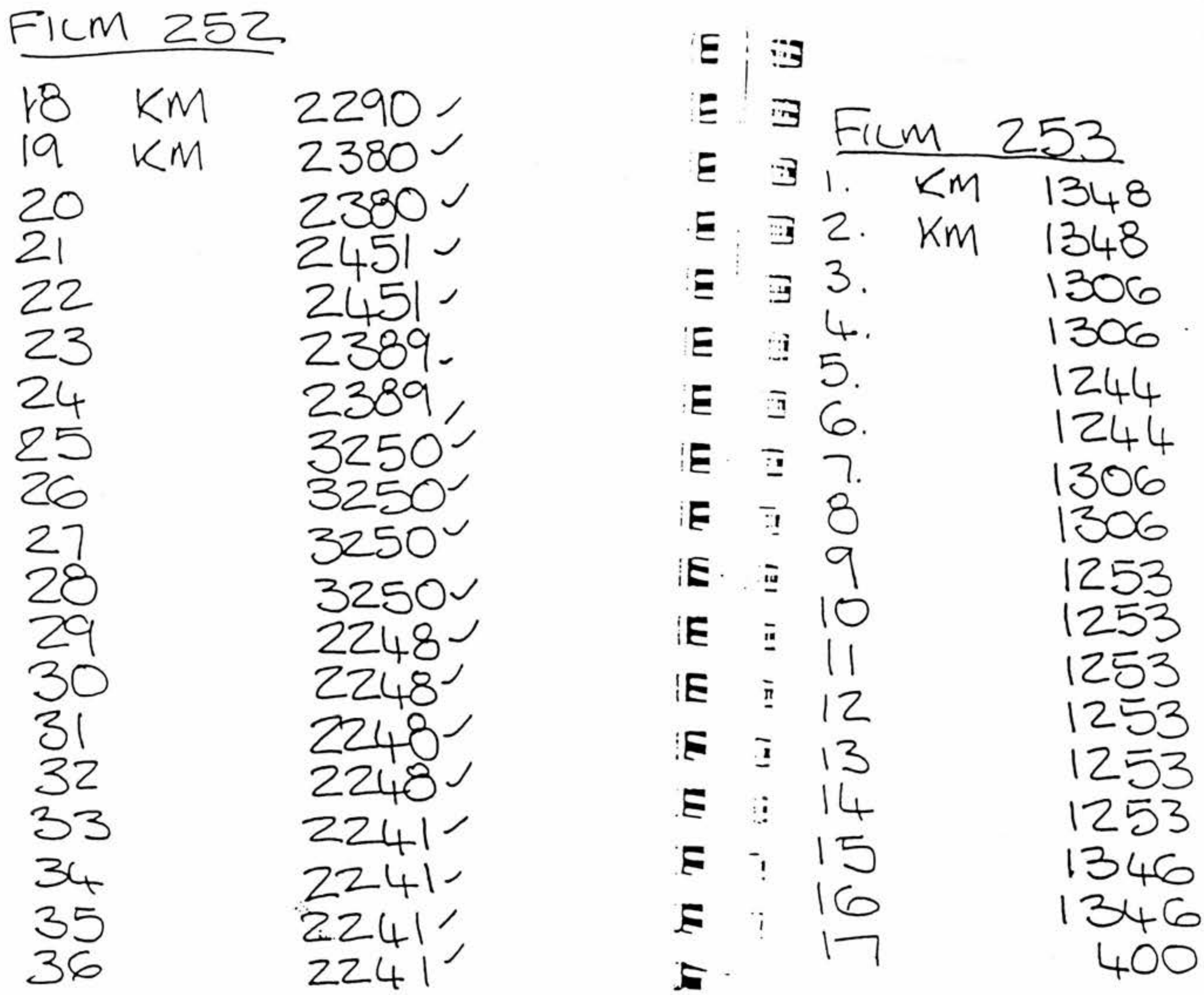
The unit plans incorporate two tables in the database. The main table incorporates columns Plnumber (i.e. the plan number), Size (i.e. whether it was drawn on A4 or an A3 size paper), and Scale.

The relationship set table connecting UNITDRAW with table UNIT_LOG is called UNDRAW and contains the Unit and the Plnumber in which it is incorporated.

4.12 Photographic Record

It was thought that for the present excavation at Kissonerga, a photographic archive would be of great benefit. The films and the frames that constitute the photographic archive, have been numbered sequentially and include both objects and site units.

The photographic record, part of which is presented in figure 15, contains data regarding photographs taken at the site. So far, there are only the small finds and the site units that have been photographed. The data have been placed in one main table, called FILM and two relationship tables - connecting table FILM with table SMALL as well as table FILM with table UNIT_LOG - named SFFILM and UNITFILM.



FILM 252

18	KM	2290 ✓
19	KM	2380 ✓
20		2380 ✓
21		2451 ✓
22		2451 ✓
23		2389 ✓
24		2389 ✓
25		3250 ✓
26		3250 ✓
27		3250 ✓
28		3250 ✓
29		2248 ✓
30		2248 ✓
31		2248 ✓
32		2248 ✓
33		2241 ✓
34		2241 ✓
35		2241 ✓
36		2241 ✓

FILM 253

1.	KM	1348
2.	KM	1348
3.		1306
4.		1306
5.		1244
6.		1244
7.		1306
8		1306
9		1253
10		1253
11		1253
12		1253
13		1253
14		1253
15		1346
16		1346
17		400

Fig. 15. Sample photographic record sheet

The reason for this separation is that a unit number may coincide with that of a small find, causing confusion. Therefore, it was for practical reasons that this decision was taken. Nevertheless, it offers an additional advantage by leaving open the option to add in the future another attribute in table UNITFILM, denoting whether the picture taken was vertical or oblique.

The film data has been placed in one main table comprising information such as the film number (i.e. Filmnum) - recorded sequentially since the start of the excavation -, its Type (i.e. whether colour or B/W), possible other information - such as for example, its Brand (e.g. Kodakchrome), Manufacturer, ASA, and the number of frames in the film (i.e. Pnum).

Tables SFFILM and UNITFILM comprise information such as the film number (Filmnum), the Type, the frame number (Stand) and the small find number (Sfnumber) of the artifact depicted in the frame. In table UNITFILM Sfnumber is replaced by Unit.

Both Filmnum and Type are considered as part of the primary key in both relationship set tables described above. The reason is that all films used at the excavation are consecutively numbered, but this is only done according to their type. Therefore, there is a chance that there might be a colour film and a B/W one both carrying the same accession number.

4.13 Flotation

Flotation incorporates three types of recording sheets. One named "Heavy Quantification", one called "Heavy Quantification Information" and the third "Sample Log", depicted in figures 16-18. Before discussing these, however, it is necessary to explain what the process called "flotation" actually involves.

Flotation is the process by which artifacts that have escaped the attention of the excavators, or that are extremely difficult to spot with the naked eye can be located and collected.

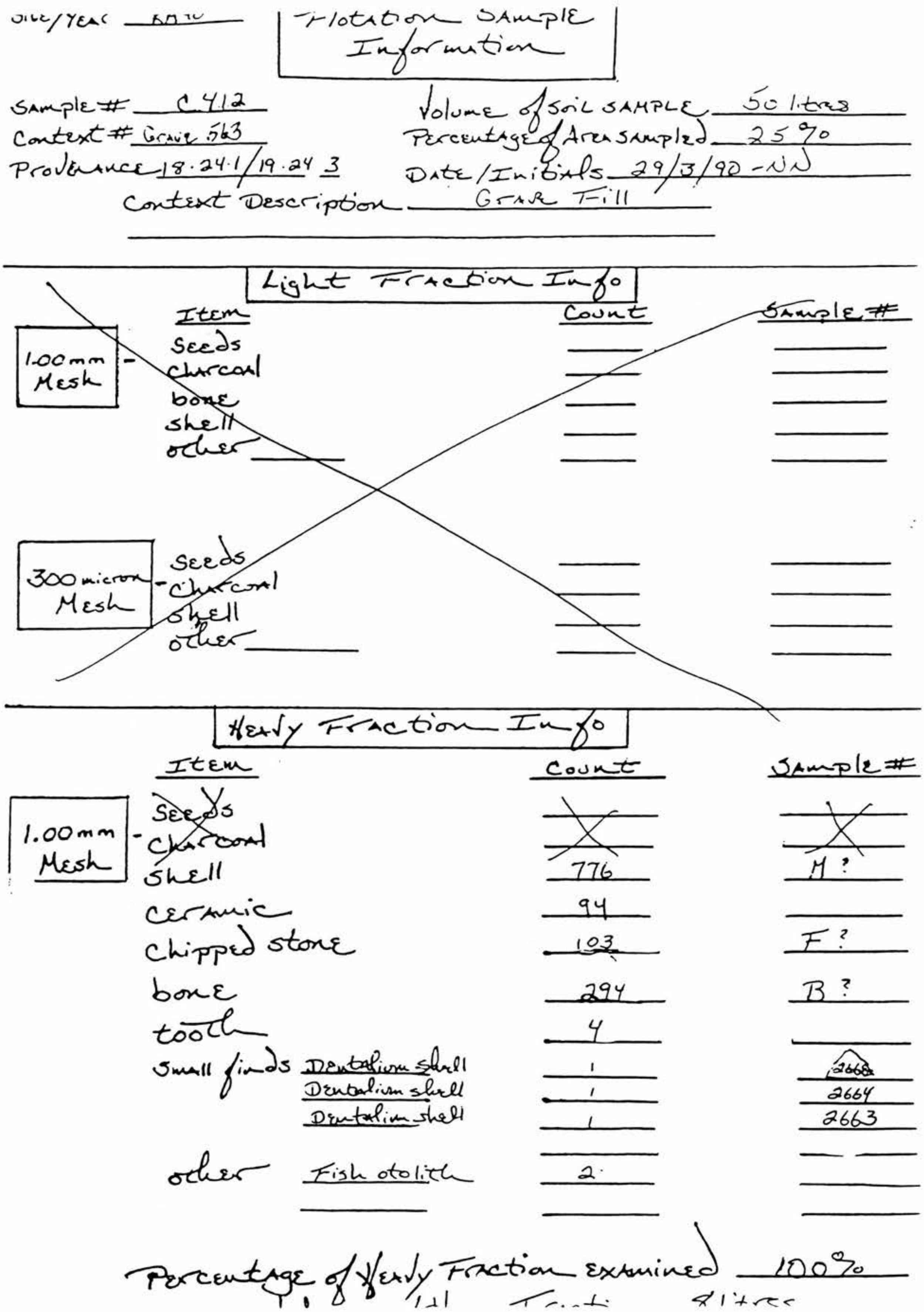
During the excavation the person who is responsible for flotation gathers soil samples from the most important units dug (e.g. graves, pits, building floors etc.). The volume of these samples is measured in litres. The sacks containing the soil are marked with the soil sample number (sequential), the unit they come from and their provenance. There are three kinds of flotation processes, as interpreted from the flotation log. These are: (a) machine flotation, (b) dry

Heavy Fraction Quantification

CERAMIC

Sample #	Context #	>1cm	<1cm >0.5cm	<0.5cm >1.0mm	Comments
C262	1059	22*	15	6	*2 rim she
C263	1038	94*	45+	9	*9 rim she +3 rim she
C264	539	10	16	6	–
C265	1093	30*	28	4	*1 rim she
C266	1095	63*	26	6	*7 rim sherd
C267	1104	12	13	–	–
C268	1064	106*	112+	35	*6 rim sher +4 rim sher
C269	1009				
C270	934	70*	90+	25	*3 rim sher +2 rim sher
C271	1090	38*	24	7	*3 rim she
C272	540	9	11	1	–
C273	974	35*	23	4	*1 rim sherd
C274	1110	16*	14*	2	*2 rim sherds
C275	1073 in 541	20*	48+	20	*1 rim sherd +2 rim sherd
C276	538	25*	15	5	*1 rim sherd
C277	539	15*	5*	2	*1 rim sher
C278	1117	5	6	1	–
C279	538				
C280	1097				
C281	1138	22*	15	2	*1 rim sherd
C282	1147				
C283	1153	19*	3	–	*2 rim sherds
C284	1149				
C285	1155				
C286	1157				
C287	1170				
C288	542	10*	12	2	*3 rim sherds
C289	1159				

Fig. 16. Sample of a heavy quantification sheet



SITE/YEAR ___ Flotation Sample Information

Sample # C412
Context # Grave 563
Provenance 18·24·1/19·24 3
Volume of soil sample 50 litres
Percentage of Area sampled 25%
Date/Initials 29/3/90 - NN
Context Description Grave Fill

Light Fraction Info

	Item	Count	Sample #
1.00 mm Mesh	seeds		
	charcoal		
	bone		
	shell		
	other		
300 micron Mesh	seeds		
	charcoal		
	shell		
	other		

Heavy Fraction Info

	Item	Count	Sample #
1.00 mm Mesh	~~seeds~~	X	X
	~~charcoal~~	X	X
	shell	776	M ?
	ceramic	94	
	chipped stone	103	F ?
	bone	294	B ?
	tooth	4	
	small finds Dentalium shell	1	2665
	Dentalium shell	1	2664
	Dentalium shell	1	2663
	other Fish otolith	2	

Percentage of Heavy Fraction examined 100%

Fig. 17. Sample of a heavy quantification info. sheet

Location SAMPLE #	Provenance	Context #	Date/Initials	Volume of Soil Sample	Percentage of Context Sample	% of extra Sample	Machine Flot.	Hand Flot.	Dry Sieved	Context Description
C393	20.24.5 [361]	contents of pit 2337	22/9/89-PWC	3L	100%		3L			Pit Fill
C394	19.24.1	[1422]	24/9/89-NN	5L	50%		5L			Pit Fill of [1345]
C395	24.23.4	[1409]	24/9/89-KF	50L	25%		50L			Bldg Fill of [1312]
C396	19.24.3	[1463]	24/9/89-NN	6L	100%		6L			Fill of [1359] [illegible]
C397	20.24.1	[1465]	25/9/89-LB	1/4L	100%			1/4L		small ashy lens in stoney layer
C398	23.24.2-4	[1464]	25/9/89-JH	50L	<10%		50L			Pit Fill
C399	20.24:3	[561]	25/9/89-PWC	6L	1%		6L			Gravel fill from around skull
C400	30.29.1	[551]	26/9/89-AXC	50L	50%		50L			Grave Fill
C401	22.24.4	[1477]	26/9/89-GDT	12L	100%		12L			Post hole in bottom of pit
C402	20.24.1	[1479] *	26/9/89-LB	66L	30%		66L			Pit Fill
C403	22.24.4	[1482]	26/9/89-GDT	4L	100%		4L			Post hole in bottom of pit
C404	23.24.2-4	[1461]	26/9/89-JH	32L	30%		32L			Pit Fill
C405	20.24.1	[1484] *	27/9/89-LB	32L	100%		32L			Lower ash layer in [1479]
C406	23.23.2	[1490]	27/9/89-KF	18L	100%		18L			Oven Fill
C407	20.24.1	[2010]	1/10/89-LB	40L	100%		40L			Pit Fill
C408	19.24.1	[1499]	1/10/89-NN	50L	100%		50L			Fill of Plaster basin [1498]
C409	19.24.1	[2024]	1/10/89-NN	50L	100%		50L			Fill of Pit [illegible]
C410	19.24.1	[2014]	3/10/89-NN	c15L	100%		15L			Fill of 2013
C411	19.24.1	[2016]	3/10/89-NN	c15L	100%		15L			Fill of 2015

Fig. 18. Sample of "sample log" record sheet

sieving and (c) flotation by hand.

Sieving takes place directly at the site. The contents of the sacks are emptied in sieves and shaken. The sieves let the smaller soil particles pass through but retain all larger ones that might include some material of archaeological importance.

Hand flotation usually involves small volumes of soil that are examined by hand.

Finally, machine flotation is the most complicated process of all. It involves a transformed metal barrel at the bottom of which a hole has been cut and a water hose has been connected. The mouth of the barrel is also cut at a point and a piece of metal has been attached in such a way that it protrudes from the mouth thus forming a spout. Below the spout sieves have been placed for particle capture. The samples are emptied in a platform attached to the inside of the barrel and consisting of a mesh of variable size. The most commonly used is the 5 mm mesh. The barrel is filled with water by means of the water hose at the bottom. When water reaches the mesh it penetrates it and overflows through the spout. Any material that floats (e.g. seeds) is carried by the water and collected by the sieve. The smallest soil particles fall to the bottom of the barrel through the mesh, or out through the sieve. The rest of the heavier particles remain in the mesh. They will be gathered, left to dry and finally, the important material will be separated by hand.

The commonest materials found during flotation are seeds (very important for environmental and economic studies), charcoal (for C^{14} dating), shells (handed over to the mollusca specialist), ceramics, chipped stones, bones and teeth (particularly important to the zooarchaeologist in identifying food patterns and kinds of animals present in antiquity). Rarely, other items that do not fall in any of the above categories are found and are marked as "other", followed by a description.

Several comments can be made regarding the three flotation recording sheets. First of all, wherever "context no" is recorded, it is replaced by the term "unit". Since both have the same meaning and some uniformity has to be maintained during information recording and retrieval. "Unit", being the most modern term, was adopted. Dates and initials are deliberately left out (as they were in the case of pottery) and replaced with the KM prefix (see pottery discussion).

With regard to the sample log, "context description" is also omitted since this is included in the UNIT table. Provenance is maintained until its use is proved. If there is eventually no real use for it, it will be deleted from the final record.

The FLOTATION table contains attributes such as Sample (i.e. the address number of the soil sample examined), Item (i.e. the item category found, e.g. seeds), Itemcode (i.e. a letter prefix defining the item category), Itsampnum (i.e. the item sample number to which the items found are ascribed), and Itcount (i.e. the number of items per category found in the soil sample).

Each category of finds located in a sample is given a letter prefix (Itemcode), denoting its material (e.g. bone, carbon etc.) and a reference number. For seeds, both the prefix and the reference number are identical to those of the sample. Pottery bears no prefix and its number matches that of the unit. Although it would be possible to create a relationship set table connecting flotation with pottery this was avoided since it was not positive that such an association would be of importance[13].

There is also a look-up table associated with

FLOTATION called FLOTYPE_CODE in which the flotation type codes are defined.

4.14 Period

The period table consists of two columns namely, column Period and column Description. The Period column states the period number and the Description includes all major points and comments necessary for clarifying the main characteristics associated with each particular period. The table is linked with the SMALL and UNIT_LOG tables with one relationship set table. Should further relationships be established in the future, appropriate modifications to the structure will be made according to the case.

4.15 The Mortuary Data

One of the most important aspects of an excavation is the collection, analysis and publication of mortuary data. Thist is mainly because, unlike the material present in a settlement, which is exposed to any form of destructive process and/or intentional and deliberate removal, the objects contained in graves are, in generic terms, "sealed". That is, they have been deposited with the intention that they should remain buried forever, and special care has been taken to achieve that aim. It is not surprising therefore, that theories on human social behaviour, explanation of the material culture and religious practices have been developed to a large extent on the basis of the study of funerary deposits.

Up to this point, the design of the database structure provided for a general recording of raw data with no intention of incorporating in-depth studies in any particular area of specialization. For example, although we record data on ceramics, we are not involved with thin section analysis, xeroradiography or any other potential special treatment of the material. If necessary, that could be achieved in the future, should the need arise, after certain amendments to the original structure have been made.

The variation in mortuary practices present in this excavation, however, calls for a special treatment of the subject. Although not as detailed as it possibly could be[14], this does incorporate a greater degree of detail, than the other areas of study catered for by the database.

4.16 The Graves

Three major types of graves are present at Kissonerga. The first is what is called a "scoop" burial (see figure 19b), in practice a very shallow pit for the deposition of infants, as encountered so far. There are neither grave goods nor any architectural features associated with these graves. Their recording therefore, will reveal the minimum of information, especially because, being shallow, they are subject to a great degree of post-depositional effects. Moreover, skeletal remains are usually poor due to the highly fragile nature of an infant's skeletal structure.

The second type of grave is the pit grave (see figures 19a and 20). It consists of a fairly deep pit (usually 80 cms diameter x 80 cms depth) at the bottom of which the deceased was placed, along with any goods that were deposited with the inhumation. Then the grave would be partially filled with soil (commonly refered to in archaeological terms as "grave fill") and a number of capstones[15] were placed on top. Then more soil was added to the top of the pit sealing the deposit. This type of grave is associated with a single interment but some may contain up to two.

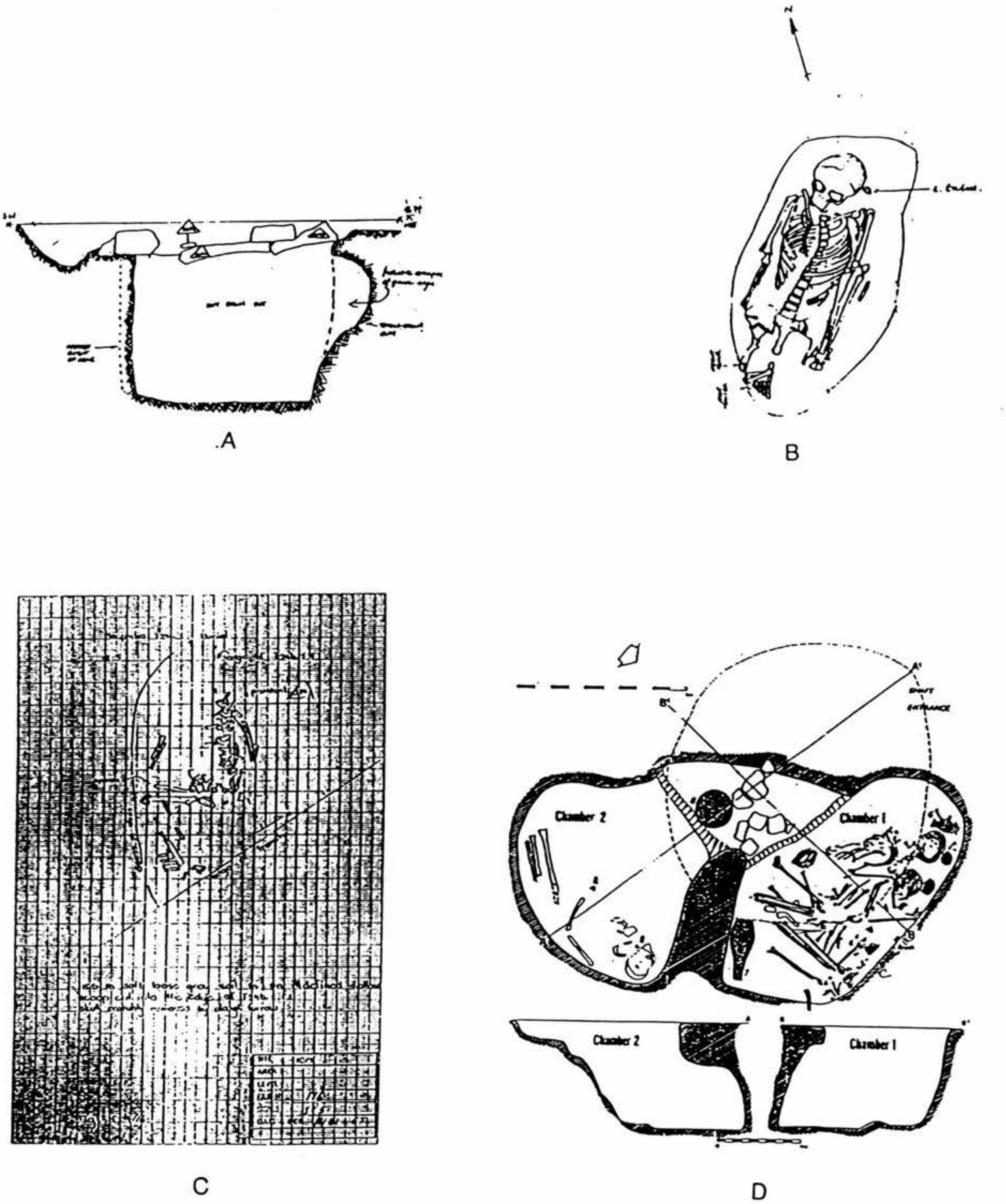


Fig. 19. Types of graves at Kissonerga

The third type of grave is the chamber tomb (see figures 19c and 20). Similar to the previous type, it also consists of a pit but at the bottom of this pit chambers have been carved into the bedrock to accommodate the dead. The number of chambers may vary from one to four. A larger number of chambers would jeopardize the rigidity of the whole structure. Each chamber could accommodate a number of burials and their goods, and each was usually sealed by a blocking stone[16]. The pit then was filled with soil.

Straightforward as the mortuary practices may sound, they involve a number of complications.

The first complication is the number of sub-types that the three categories of graves, outlined above, may have. For example, a double chamber tomb at Kissonerga presented a feature like a platform located in front of the entrances of the two chambers. On it grave goods were placed (see figure 19c). Obviously we cannot associate these goods with any one of the chambers, but we have to assume that they were common to both (Peltenburg, 1991, pers. comm.).

There is a chance that where more than one body is contained in a grave the other body (or bodies) were buried sometime after the first and new

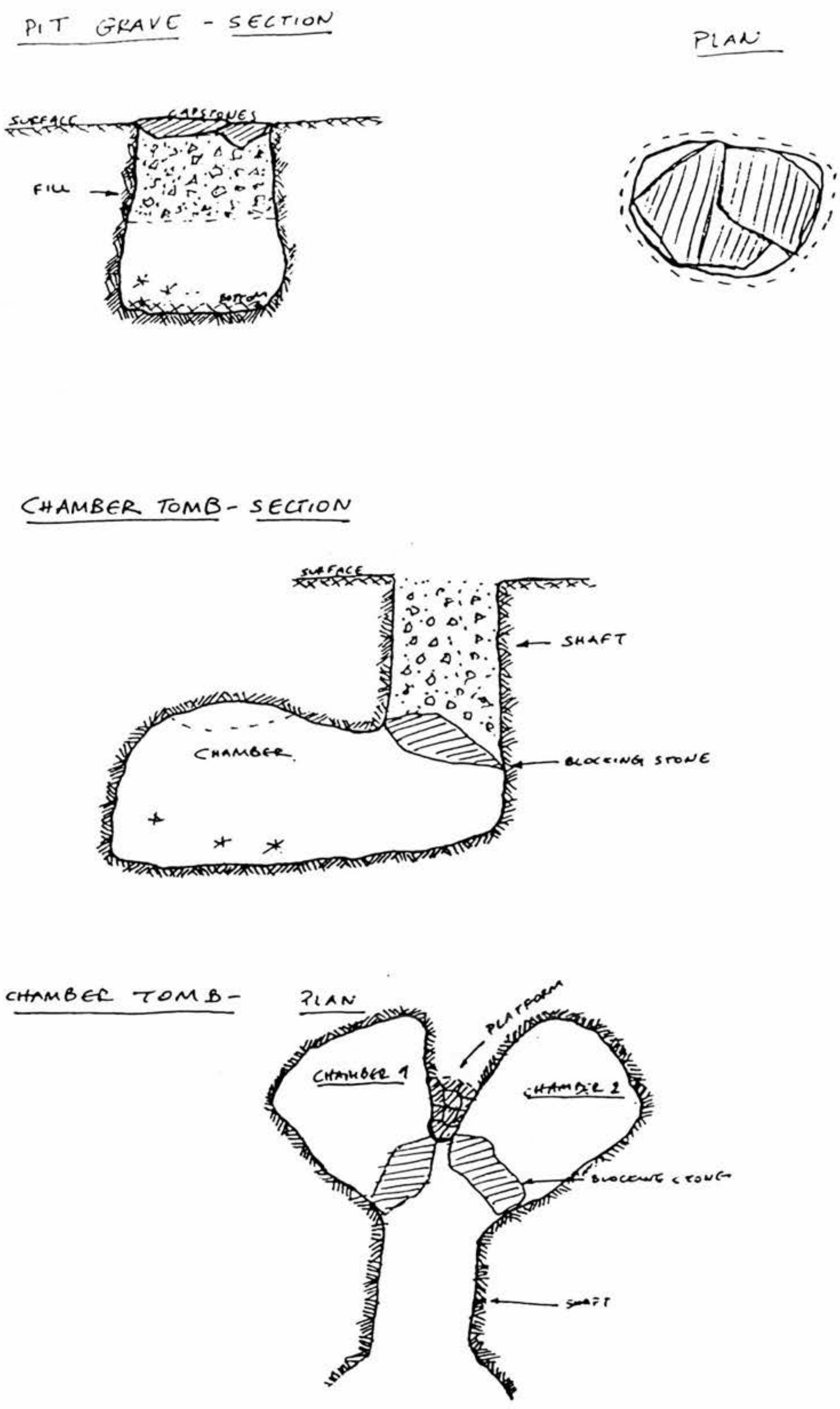


Fig. 20. Overview and sections of pit and chamber tombs

grave goods were added to the deposit. Especially true in the case of chamber tombs, this fact adds to the complexity of the process of dating a funerary deposit or trying to establish associations between grave goods and individual inhumations.

The third and final complication is associated with the fill of the grave. In many instances the unit log contains entries such as "upper", "middle" and "lower fill" of a unit. This type of recording denotes that the lower fill is the soil located at the same absolute level as the burial. Anything found in this deposit is directly associated with the burial. Middle fill is the soil located above the burial and below the capstones. Upper fill is the soil above the capstones and in general, the soil that covers the grave. Unless the grave was found sealed, by a floor for example, then it was subject to disturbance and therefore the upper fill is very unreliable in its contents.

4.17 The Mortuary Section of the Database Structure

The information on the attributes of the mortuary data has been collected from three sets of excavation recording sheets, namely the Unit Sheet (see figure 21), the Mortuary Data Recording Sheet (see figure 22) and the Grave Sheet (see figure 23).

Site .... Year ....

A	Unit	Period/Phase	Contam	Location	as.l.
			Y/N/M		t b

B Class 1 General 2 Surface (unpaved) 3 Floor (paved) 4 Basin 5 Building 6 Entrance 7 Hearth 8 Grave
9 Posthole 10 Pit 11 Wall 12 Plaster & Paving 13 Stone setting 14 Stake-scape 15 Channel (groove)
16 Misc. 17 Fill 18 Potspread

Type ....

C Dimensions

1	2	3	4	5	6	7	8	9	10

D Relationships

above	below	contemporary adjacent	part of

E Composition

Type	pisé ash piséwash plaster sand silt clay
Colour	white black brown reddish grey yellow
Structure	crumb cloddy blocky prismatic laminated ash fine medium coarse
Consistency	loose friable compact hard sticky soft
Organics	charcoal shell bone roots dense medium sparse
Clarity of horizon	top sharp fair merging
	bottom sharp fair merging
Particle Type	stone cobble pebble gravel grit sand
Sherd concentration	dense medium sparse none

F Artefacts

Small Finds ....

Pottery ....

G Samples F flint, B bone & antler, S soil/stone, C carbonized seed, R C[14] assay, M mollusca

H Plan. Section Photo

BW ....

Col ....

Description (on back)

Fig. 21. Sample of unit sheet

MORTUARY DATA RECORDING SHEET

1.

SITE	REFERENCE	UNIT	PERIOD	TYPE	TOTNUMBUR

2. BURIAL STATUS

BURIALNUM ______ STATUS ______ TYPE ______

POSITION ______ AGE ______

FACING ______ SEX ______

ALIGNEMENT ______ PATHOLOGY ______

3. ARCH.STATUS - CHAMBER TOMBS

NUMBLOCKSTONES ______ CHAMBERHEIG ______

TOTALNUMCHAMB ______ SHAFTLENG ______

NUMBURCHAMBER ______ SHAFTWIDT ______

CHAMBERLENG ______ SHAFTDEPTH ______

CHAMBERWIDT ______ ROOF STATUS ______

4. ARCH.STATUS - PIT/SHAFT GRAVES

NUMCAPS ______ PITDEPTH ______

CAPSSFNUM ______ PITWIDTH ______

SHAFTLENG ______ APERTURE ______

5. ARCH.STATUS - THOLOI

THOLOSLENG ______ DROMOSLENG ______

THOLOSWIDT ______ DROMOSWIDT ______

THOLOSHEIG ______ DROMOSALIGN ______

REMARKS

1.

2.

3.

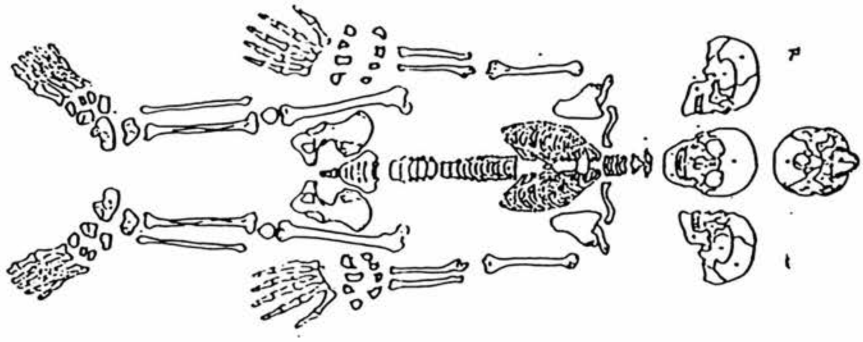
4.

5.

GENERAL COMMENTS

Fig. 22. Sample of mortuary data recording sheet

GRAVE/BURIAL RECORD	SITE	PHASE	S.F.	No.	DATE	INITS
	KM 89 TAT 90	4	2338	561	20/7	[illegible]



BURIAL

Position: Flexed inhumation
Facing: NNW
Alignment: E-W head to E
Levels: 41.17m on skull
Depth from top of pit: 1.05m
Remarks:

Articulated: yes
Age: adult
Sex: ♀
Bone Cond.: fair
Pathology: ✓

GRAVE

Type: Small stepped chamber
Shape: oval
Capstones: /
Embankment: /
Aperture: ?

Dimensions of top 'hollow':
" " pit: see plan
Alignment of pit:
Fill: generally fairly loose grey brown ashy silt with a few stones and lumps of compact mud/[illegible]

Remarks: Entrance to chamber presumably obliterated by cutting of pit [1110]. Then frost + collapse of chamber roof caused large aperture to grave [illegible] excavated. NE margin of chamber outside of pit [1491] - edge not reliably traced here. E & S margins of chamber cut 1492 pit, top of which forms most of floor of chamber - edge not reliably traced in most of this sector [illegible]. W & S(W) margin of chamber cut into natural [illegible], therefore reliably [illegible]. [illegible] 2336 + 2337 placed upon feet of skeleton

ASSOCIATIONS

Area: 20243
Unit: [illegible]
Cuts: 1491 1492 Cut by 1110
Remarks: 2340 located ca 15cm fr. S edge of pit, + ca 25cm [illegible]

Position:
Finds: 2340 conical stone, 2341 [illegible] 2321 [illegible]
Finds relation to body: 2336 conical stone, 2337 RB/B spouted bucket (sample)

RECORDS

Photos: B/W. No. 248., Fr. 28 - 32 / Col. No. 125. 12-14; B/W No. 249 [illegible]; Col. 125. 23, 24; B/W No. 249/19-26; Col. 128 Fr. 25 - 32
Sections / Plans: See back of gr. sheet B.1628. R.1339 R.1376 F.1269 F.1229

Treatment: M.921, M.926, M.977
Samples taken from: C393 [illegible] contents of ceramic vessel 2337, [illegible] from beneath [illegible] of vessel 2337. C399 grave fill

Fig. 23. Sample of grave sheet

From the point of view of the grave specialist the information gathered should deal with:

a) general information regarding the grave as an entity,

b) the architectural features of a pit grave (different in each case),

c) the architectural features of a chamber tomb,

d) the architecture of each chamber within each tomb and finally,

e) data associated with the burials in relation to the tomb and/or the chamber in which they were located.

Three entity tables, two relationship set ones, and one look-up table are dedicated to the recording of mortuary information.

The GRAVE table contains the following attributes:

a) Grave (the unit number addressing the grave),

b) Type (the type of the grave, for example pit or chamber and any sub-variations that might be),

c) Tnumbur (the total number of burials located in the grave),

d) Tnumchamb (the number of chambers in a chamber tomb),

e) Numcaps (the number of capstones in a pit grave),

f) Aperture (description of the construction of the grave's aperture),

g) Shleng, Shwidth, Shdepth (the dimensions of the grave's shaft),

h) Rem1, Rem4 (remarks on the grave as a whole and remarks regarding the pit grave category).

The CHAMBER table will contain the following attributes:

a) Chamber (the address number of the individual chamber[17]),

b) Chnumbur (the number of burials in the particular chamber),

c) Numblock (the number of blocking stones sealing the chamber),

d) Chleng, Chwidth, Chheight (the dimensions of the chamber),

e) Roofstatus (comments regarding the condition of the chamber's roof),

f) Rem3 (remarks on the individual chamber).

The BURIAL table will contain the entries listed below:

a) Burnum (the address number[18] of the individual burial),

b) Position (the position in which the skeleton was found; for example, "contracted"),

c) Facing (the side towards which the skull was facing),

d) Alignment (the geographical alignment of the skeleton, e.g. NW-SE),

e) Burstatus (the condition of the remains, e.g. "articulated"),

f) Type (the type of burial, e.g. "pithos burial"),

g) Minage (the minimum estimated age of the deceased),

h) Maxage (the maximum estimated age of the deceased),

i) Sex (the sex of the deceased),

j) Pathology (recording any evident indication of disease, cutting marks etc. on the bones) and finally,

k) Rem2 (any remarks related to the particular burial).

The look-up table called GRAVE_TYPE associated with table GRAVE contains attributes such as Type and Description.

According to the rules discussed above which govern the design of a relational database structure (Howe, D.R., 1983) three relationship set tables should exist, one relating GRAVE to BURIAL (i.e. GRBUR), another relating GRAVE to CHAMBER (i.e. GRCHAM) and the third relating CHAMBER to BURIAL (i.e CHAMBUR). In this exceptional case, however, table GRCHAM can be replaced by table PART_OF (a chamber is part of a grave) which already contains the necessary information to make the connection, and tables GRBUR and CHAMBUR can be replaced by table SFUNIT since the burial number is a small find number (see endnote 18) and both the grave and the chamber in question carry a distinct unit number.

To test the efficiency and validity of this rather perplexing structure design, test runs involving hypothetical data were carried out and both the queries and the outputs produced are listed in Appendix II.

The outcome of this study proved that although such runs are processor and memory intensive, and require the construction of complex queries to be run, at the same time it is more efficient when it comes to recording the information and prevents the duplication of relatively large amounts of data. The latter would cause great concern especially when an update of information is being considered.

It can be argued of course that the way table UNIT_LOG (see discussion on section 4.7) has been constructed is not an efficient one and that groups of entities should be divided into categories according to class, and that separate tables should be created. The counter-argument is that there are already eighteen such class groups, one of which is called "miscellaneous" which would eventually call for a further breaking-up of its structure. The creation of eighteen entity tables therefore, along with all the linkages that would be required would be even heavier on machine resources. Given also the fact that there was no request on behalf of the experts for such a detailed recording to be followed by a significantly detailed analysis the whole exercise would have been conducted in vain.

4.18 The Pottery - Small Finds Relationship Problem

There is one remaining problem with the structure that has been identified, but possible solutions to it are still under discussion at the present time prior to any action being taken. The nature of the problem can still be examined, however, eventhough no final conclusion can be provided at this juncture.

The basic question underlying the problem is as follows: "Should there be a relationship established between the small finds and the pottery tables?".

The theory behind this question is that individual pottery sherds found during excavation are recorded in the POTTERY table only. Should a pot be found intact in situ, it is registered in the SMALL table only. If however, the conservator, while examining the sherdage gathered, discovers pieces that are part of a broken pot and this pot is later reconstructed, then those sherds will have been registered initially in the pottery table as various pottery sherds - and in the small finds table - as a single pot; in other words they will have been recorded twice.

It may sound a complicated argument for a trivial case that many could ignore but let us consider this case as an example:

Let us imagine that a pot has been reconstructed but certain parts of it are still missing. Two cases are then possible, (a) that the missing pieces are lost either during excavation or through time due to site disturbances or other related factors, or (b) that the pieces are there but were not identified during the conservator's search[19]. Thus, the only record which can tell whether sherds of a certain ware type, class and item are present and from which unit they come, is the POTTERY record. If the latter argument is correct then a small finds-pottery link is important. The construction of this link however is a complicated process since many factors have to be taken into consideration (e.g. sherds found during flotation). There may even be a need for updating the small finds and pottery recording methods, or it may even call for the creation of a conservation record to act as the mediator between the two.

4.19 Conclusion

The present demands from the Kissonerga database are:

a) to provide means for efficient storage, updating and retrieval of information acquired from the site,

b) to provide initially simple information (e.g. what was found where),

c) to be able to produce output tables readily formatted for use in the publication, and

d) to be able to be interfaced with other packages for reasons of depicting artifact location in relation to the topology (e.g. an ORACLE - ARC/INFO interface) and/or of producing graphic statistical outputs (e.g. the ORACLE - GIMMS interface[20]).

In any case, the system should perform relatively fast operations with the aim of providing quick answers and possibly immediate solutions to problems directly on the site during the course of excavations.

The process of excavating a site is a destructive procedure (Morrison, I.A., 1987). Each layer that is excavated is afterwards irreconstructable and should a mistake occur, it is generally impossible to go back and make a new beginning. A fast operating database system therefore, will be a very useful tool in identifying the problems as they arise, at the earliest stage possible, and correcting them through updating operations which again will be tested for possible new errors. Such operations are presently very difficult and time consuming to perform without the aid of a computer. This is due to the considerable volume of paperwork that has to be processed in order to complete this task, while at the same time the excavation-"destruction" still goes on. Supporting this view is the general feeling expressed at the "Computer Application in Archaeology" conference (University of York, March 1989) that personal computers should be used directly in the field, rather than relying on mainframes located back at the laboratory (Ives, D.J., and Arroyo-Bishop , D., 1989). Moreover, the use of a computer will impose controls on the standards and the format of the data inserted. This will introduce a certain degree of uniformity to the recording methods in use.

Besides the fact that the present database is the first one developed for the recording and analysis of an East Mediterranean prehistoric excavation, there are also a number of other novel aspects which are incorporated in the particular database approach. Foremost, is the fact that for the first time the data model developed has been presented, accompanied by a complete analysis of the processing and analytical requirements of the excavation, as well as a statement of the requirements pertaining to the construction of a database relational model. Thus far these areas had been kept separated with reports concentrating either on theoretical issues regarding database use (e.g. Chenhall, R.G., 1981; Wilcock, J.D., 1981; Smith, D., 1991) or on general descriptions of particular applications (e.g. Arroyo-Bishop, D., 1989; Desse, J. and Chaix, L., 1986; Powlesland, D., 1991). In the latter case, however, there is a distinctive absence of data model documentation (i.e. the data model is not included in the report).

The particular database has been constructed to accommodate all data deriving from an excavation in an integrated fashion without restricting its application to any particular research area or splitting the information into a number of separate databases. The main tables were constructed based on the pro-forma recording sheets employed by each individual specialist involved in the project. In other words, the database evolved on the assumption that it was archaeology that determined how computers should be used and not computers dictating how archaeology should be conducted.

The RDBMS also maintains a link with the GIS which automatically provides the spatial references of the items in question. They both constitute the heart of a system which incorporates a significant number of other software packages, and which is capable of conducting a complete integrated excavation analysis.

Finally, another innovative aspect of the current approach is the way in which archaeological recording in general is envisaged by the current project (i.e. KAIS). Although this aspect will be treated more fully in the concluding chapter, nevertheless it can be stated that the intention of the system is not only to provide a continuous flow of data from the excavation to the final publication but also to expand the dissemination of archaeological information by integrating data categories such as survey, excavation, conservation, and bibliographic data, specialist reports, and museum inventories within a single relational database structure.

The limitations of the Kissonerga project database derive from the fact that we are dealing with an almost completed excavation. Given that planning for the structure and the end-use of the data are the most important elements to be considered prior to the implementation of a database structure, in this case we still have to face the fact that this had already been done in part by the excavators without formal methods of database design to guide them. There is no possible way in improving on recording systems already used in six consecutive seasons on the site. Even if this were possible, the artifacts are not there any more and all that it is left is their recording sheets. On the other hand, problems arising from the use of the particular recording system can be isolated and suggestions for future improvements can be made.

The other constraint is that the extent to which the system will revolutionize recording methods greatly depends on the good will of the specialists. These are the best suited to identifying current problems associated with the methods in use, and visualizing possibilities for the future. No matter how diligently one investigates the subject, there is no better aid than an experienced scientist who has mastered his field and looks upon his profession from a realistic point of view, weighing the pros and the cons and waiting for new possibilities to acquire more powerful tools for even better results.

The final problem is how to make the system available to archaeologists without computer training who are willing to learn its use but find it very difficult under the pressure of time and ever shrinking excavation budgets. Even acquiring the necessary hard-ware and software for a complete GIS might cost as much as a whole, or even several excavational seasons.

The immediate proposal is to make available readily constructed queries, in the form of macros, that the specialist will run to answer standardized questions (e.g show all the pottery present in Unit 1095) of both simple and more complex types. The only requirement for the user will be to supply the values on which data selection is based, thereby conserving time, and effort and making the learning curve as short as possible. A number of such standardized queries is presented in Appendix III.

Chapter IV - Endnotes

[1] Note that the trainees were young undergraduate archaeologists who apart from processing information they also had been assigned the task of excavating.

[2] Synthesis is the interpretation of the archaeologist on the functionality and importance of the site being published. It is mainly a subjective view based on the evidence resulting through the excavation process.

[3] This by no means implies that the suggestions made in "Archaeological Excavations at Lemba (Lakkous), Cyprus" initiated those alterations, since changes had already been made at a far earlier stage.

[4] Except in the case of tables GRAVE and CHAMBER. For more details see the discussion on mortuary data recording, further on in this chapter.

[5] It is recommended that the term "context" should be avoided because it is also frequently used by some excavators as synonymous to "unit".[3] The study of mortuary data may involve a series of specialists such as a dentitian, an anthropologist and a palaeo-pathologist. Although they will be working with the same set of data, their information requirements and methods of recording will vary considerably.

[6] After six years of excavation this number has become standard as no new ware types are coming into light.

[7] Sometimes predicted diameters of pottery vessels are recorded as a form of notes on the back of the recording sheets. The preliminary study of the material showed that no more than five values were recorded. In any case however, should more appear further columns can be added to the table without disturbing the contents.

[8] The second table structure proposal was finally adopted and there was no reason to modify these entries because instead of column names (on which the ORACLE restrictions apply) they became character entries with no restrictions applying whatsoever.

[9] After the sherds have been washed, sorted, analyzed and recorded, only those that are unique or of great interest are kept. The rest are disposed of with all formality at pre-arranged sites.

[10] Nevertheless, in case an artifact had a double

purpose (i.e. two uses) and these purposes have been identified by the specialist it is recorded twice bearing the same small find number but a different class. Moreover, when a cache of artifacts is located there is a chance of bearing the same small find number even if there were more than two artifacts. In this case the problem was overcome by adding decimal places to the main number (e.g. 35.01, 35.02 and so on).

[11] The Type entry would still remain of type character however, because of the presence of alphanumeric pottery codes (e.g. 1F).

[12] The small finds table of the Kissonerga-*Mylouthkia* rescue excavation has exactly the same format as the one developed for Kissonerga and is coded as table MSMALL.

[13] If pottery pieces found are too small then no proper analysis of them can be made. If on the other hand were larger, they would have been spotted by the excavators. Pottery is there mainly for statistical purposes only according to my opinion.

[14] The study of mortuary data may involve a series of specialists such as a dentician, an anthropologist and a palaeopathologist. Although they will be working with the same set of data, their information requirements and methods of recording will vary considerably.

[15] Very often some, if not all, of the capstones proved to be disused tools such as querns, anvils or even broken basins. In this case they constitute small finds and are registered accordingly.

[16] At Kissonerga, the case is that the blocking stone has been replaced by a "step" which had been carved in order to provide a platform for those carrying the dead to stand on while depositing the body.

[17] Adecimal denomination of a number in the 500 range will be assigned offering a quick visual association between grave and chambers. For example, unit number 500.1 refers to chamber 1 in grave 500.

[18] This number is a small find number (i.e. SFNUMBER) and it most commonly refers to the skull due to the fact that the burial may be disarticulated. Skulls, consisting of the strongest bones found on the human skeleton, usually survive destructive processes.

[19] For a more thorough discussion on pottery quantification see Orton, C.R., 1975; ibid, 1982; Shennan, S. 1988; Vince, A.G., 1977.

[20] In this case, much thought is given whether to use GIMMS or QUATTRO (which is already being used by the Department of Archaeology). Both choices have their cons; GIMMS due to its rather complex operation language, which may be proved very time consuming to learn by the new users, and QUATTRO due to the lack of an existing interface with ORACLE which will have to be developed. In general however, GIMMS represents the complex idea, while QUATTRO the simplistic one.

CHAPTER V

Implementing the System II: Mapping the Site

5.1 Introduction

Having constructed the database for the retrieved archaeological information it is now necessary to develop a strategy for the digital recording (i.e. mapping) of the site.

In doing so, the available information must be evaluated and a method should be developed by which the graphic information stored in ARC/INFO can be linked with the tabular ORACLE data in order to provide a fully integrated system of archaeological data recording and analysis. At least some familiarity with some of the ARC/INFO functions and facilities is assumed but some basic concepts of the ARC/INFO GIS need to be reviewed. First, however, some theoretical issues will be discussed since they have direct relevance to the decisions taken with regard to the digital recording of the site plans.

5.2 Theoretical Issues Related to Intra-Site Automated Mapping

There are a number of issues that have to be addressed before attempting to embark on a project which involves mapping an archaeological site with a GIS. These issues are related to the scale chosen for mapping, the degree of error that the digital map will involve, data uncertainty, and data integrity.

5.2.1 Scale and Error

It is self evident that the larger the scale at which a feature is recorded, the more detail its representation will incorporate. Similarly, the smaller the scale becomes, the greater the generalization and hence the possibility of error.

The scales used for archaeological drawing internationally are varied. In Kissonerga large features (e.g. floors, walls, buildings) are drawn at a scale of 1:20. The smaller features (e.g. graves, pits and their contents) are usually drawn at a scale of 1:10 for improved legibility and clarity. General archive site plans are drawn at smaller scales, depending on the size of the site. In this particular case the archive plan scale chosen was 1:50.

It is the intention of each excavator to provide a record of the excavated site, which is as accurate as possible. However, the term "accuracy" in intra-site archaeological mapping does not bear the same significance as, for example, in cartography. Archaeological mapping is prone to constant error since it is based on manual methods and subjective interpretations.

Plan spatial referencing is handled by means of a number of control points (e.g. a number of metal rods planted in the ground at regular intervals) which have been set up at the beginning of the excavation. These control points are prone to slight shift due to several factors. These include natural ground shift due to soil instability, accidental disturbance during excavation and so on. As a result, measurements taken in relation to those points can be inaccurate. More inaccuracy is introduced depending on the competence of the person drawing each plan (not necessarily the draughtsman) and the conditions under which this person draws the particular plan (e.g. it is completely different drawing a plan from a comfortable sitting position and attempting the same exercise in a grave chamber with poor lighting, narrow spacing, and collapsing surfaces). Finally, the manual means employed to take measurements (e.g. tapes, strings, nails, and plumb-bobs used in triangulation) can also introduce a degree of error. Using more automated methods like electronic theodolites (when available) could lessen the problem of inaccuracy but they will not eliminate it entirely.

On the other hand, even if accurate measurements could be obtained, this would not be of great significance since the location of features and objects is often random. One can hardly imagine people in antiquity carefully arranging their objects with the intention that future archaeologists should find them in exactly one particular spot. Fisher (1991) has said that a map is an abstraction of reality since what it is depicted on it was true only at the moment the map was made. Similarly, archaeology uncovers only an abstract of past reality. To try to achieve accurate re-presentations of two abstract pictures (i.e. archaeological drawings and past reality) is as a consequence doomed to failure. What digitizing offers in this case is that proliferation of errors (which in fact could accumulate through repeated manual map reproductions) is brought to a halt once the plans are inserted into the computer.

The present exercise had the intention of capturing the ground plans at the best scale possible (e.g. 1:10 and 1:20), and then generalizing to draw at smaller scales. This, however, proved impossible because these plans contained so many discrepancies that they were unusable for practical purposes. Any attempt to rectify them would have demanded a considerable amount of time and collective effort by all the researchers involved. This was impossible at a late stage in the project work. Therefore, the only remaining solution was to use the most complete drawing set which was the 1:50 plans.

5.2.2 Data Uncertainty

Data uncertainty is a prominent feature when dealing with archaeological excavations. In reviewing excavation archives one can encounter terms like "sealed", "disturbed", "mixed", "contaminated" and so on. They all refer to the condition of the excavated units according to the excavator's best estimate. A "sealed" unit is a deposit for which one can make accurate observations. All other terms express degrees of uncertainty with regard to the state of the unit and the accuracy of observations that can be derived from it. In order to confront this type of data uncertainty the Unit_Log table in the database contains the attribute <u>Status</u>. In this attribute column a code is recorded thus attaching one of the above described terms to each excavated unit. Consequently, the GIS could be instructed to plot all "sealed" units (i.e. c. 100% certainty), or any other status subcategory.

There are instances where the boundaries of a certain unit are "fuzzy". In other words, the edges of a unit are not certain and tend to become mixed with other features. This type of uncertainty should also be treated if any conclusions are to be drawn.

There are three ways of treating such uncertain archaeological boundaries in a GIS environment. The first method is to ignore the case completely and record only the visible edges and not the "suspect" ones. However, there is a significant danger that such a decision could lead to misinterpretation not only of the feature as such (e.g. actual dimensions, relation to other features) but it could also upset the stratigraphic sequence at the particular area of the site.

The second method is to establish a buffer zone around the uncertain boundary and use a special line type to indicate the possible extent of the polygon edges. Again there is a danger of introducing false assumptions and what is more, aggravating the problem by apparently plotting boundaries that in fact are not present.

The third solution, which according to this thesis is the most preferable one, is to depict the uncertain area by a polygon and designate it as "a possible extension" of a particular unit. This designation could be achieved by recording the term in the Unit_Log in the database and at the same time assigning another type of code in the GIS (e.g. special shading). When developing the stratigraphic sequence matrices this unit can be "tried" against others and if it fits it will be kept, otherwise it will be dismissed. If a definite decision cannot be reached, alternative stratigraphic sequences can be produced, passing the problem of interpretation to potential future researchers.

5.2.3 Data Integrity

Data integrity, as envisaged in this particular case study, is set to the highest level of the AIS structure. This means that the main concern is to achieve a high level of compatibility between the data sets that move through the different components of the system and mainly between the RDBMS and the GIS.

Despite a few technical difficulties (which are explained further on in this chapter) there were no other obstacles preventing the data sets from becoming integrated. The main reason for this is that the excavation's archives were the only source for both digital and tabular information and by monitoring data updates major discrepancies could be avoided.

Nevertheless, there is an adequate literature on the subject of data integration within a GIS environment, epecially when the data sets are obtained from a number of diverse sources, such as different GISs, remote sensing platforms, and EDMs. With particular reference to archaeology, the subject has been treated by Zubrow and Green (1990) who have identified some of the problems most likely to occur when combining different types of data. They provide guidance on how these problems may be overcome. A more thorough treatment on the subject is provided by Stine and Decker (1990). In addition to outlining the most diverse sources of digital data for archaeology they also call for some form of standard procedure to be followed when producing digital data, and for a proper recording of map coverage production methods to be supplied for possible verification.

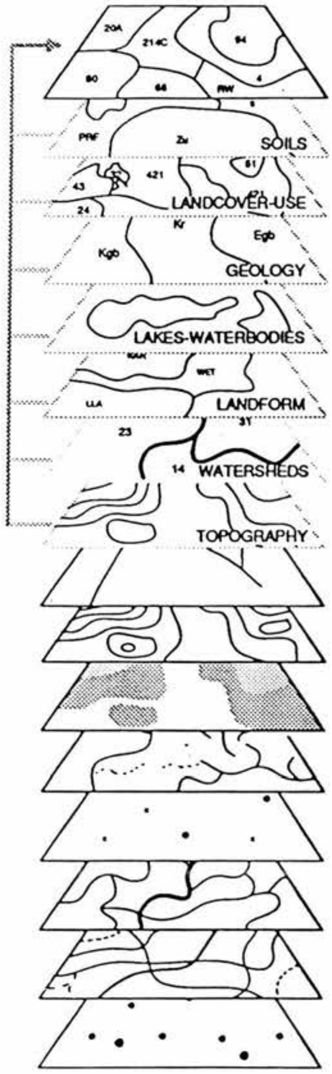
Following the discussion of some of the theoretical issues pertaining to the digital recording of archaeological site plans, we will now proceed to discuss the more practical aspects of automated mapping.

5.3 The Map Coverage Concept in ARC/INFO

ARC/INFO is a vector based GIS. This means that it is capable of handling features such as arcs (i.e. lines), points, and polygons (i.e. areas) by storing them as coordinate strings, as well as attribute data associated with these features (ESRI, 1987a). Points are used to represent features whose area is too small to be represented by a polygon, for example small find location spots within a building, or are unable to be depicted by a polygon (e.g. centroids). Lines represent linear features such as streams and rivers, and polygons are used to represent homogeneous areas, such as walls, floors, general surfaces etc. Each polygon is assigned a label point. This label point bears a set of X,Y coordinates marking its position and an ID-number used to uniquely define the particular polygon.

When transferring data in digital form from a conventional map sheet or site plan to the computer it is necessary to separate the features and store them in different files called coverages. These coverages may be used on their own to construct a final map, or a sequence of independent coverages may be combined to achieve the desired end result (see figure 24).

Each coverage is stored in ARC/INFO as a directory containing a set of files. It is not necessary to discuss all of them at this point except three of the most important. These include the .BND, .TIC, and .PAT



LAYER NAME:	ATTRIBUTES:
TERRAIN UNITS (polygons) Input Scale: 1:50,000 to 1:100,000	•Soil Types Component Texture Depth Slope Drainage Erosion pH Nitrogen Phosphorus Potassium •Landcover/Use Dominant Species Canopy Closure Stem Denisity Mid-Story DBH •Geology •Lakes and Waterbodies •Landform •Watershed Basin •Topography Type
FAULT (lines) Input Scale: 1:50,000 to 1:100,000	• Type • Name • Hazard
ELEVATION (lines and points) Input Scale: 1:50,000 to 1:100,000	• Elevation
SLOPE-ASPECT (polygons) Input Scale: 1:50,000 to 1:100,000 Derived from ELEVATIONS	• Slope • Aspect • Surface-area
STREAMS (lines) Input Scale: 1:50,000 to 1:100,000	• Name • Type • Width • Periodicity • Order
WELLS-GAUGING STATIONS (points) Input Scale: 1:50,000 to 1:100,000	• Well Number • Gauging Station Number • Springs • Basin Number
OWNERSHIP/ADMINISTRATIVE (polygons) Input Scale: 1:50,000 to 1:100,000	• Owner(s) • Township/Range • Section • County • Local Districts • State Districts • National Districts • Mineral Leases
TRANSPORTATION LINES (lines) (Roads, railroads, etc.) Input Scale: 1:50,000 to 1:100,000	• Name • Type • Width
SETTLEMENT/POINTS OF INTEREST (points) Input Scale: 1:50,000 to 1:100,000	• Type • Description (house, historic, archaelogical)

Fig. 24. Layers of a natural resource database

files.

The .BND file contains the minimum and maximum coordinates of the coverage, the .TIC file contains the tic (i.e. geographic or registration control points of the coverage) ID-numbers and coordinates, and the .PAT contains polygon and/or point attributes (ESRI, 1987a). All these files are incorporated in the INFO database and their attributes can be related with the ARC coverage features via a pointer, such as polygon ID-numbers (see diagram below).

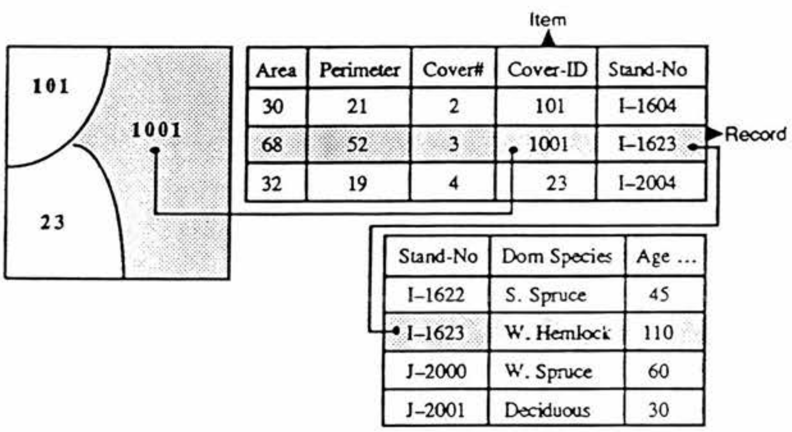


Diagram reproduced after ESRI, 1987a

In addition to the above, ARC/INFO possesses facilities which enable coverage features to be related to attributes stored in an external database, such as

ORACLE. Moreover, tables from the INFO database can be transferred into ORACLE and vice versa. All these are achieved with the use of three commands: INFOORACLE, ORACLEINFO, and RELATE, which invoke the relational database interface (RDBI) to ORACLE.

INFOORACLE is the command which allows an INFO table to be imported into the ORACLE database. Conversely, ORACLEINFO is the command which allows an ORACLE table to be imported into the INFO database. The use of the RELATE command is quite different.

The RELATE command allows relational joins to be made on the basis of a common column/item between tables or files in two different database management systems, one of which is INFO.

The command is issued at the ARC prompt and then the computer initiates an interactive conversation with the user to establish the relate environment. The information required at that stage is the relation name, the table which is to be accessed and the database in which it is stored. In addition the user is required to supply the item name in the feature table which will be used in the relate, the name of the external attribute column to which the feature attribute will be related and the relate type that will be used. All this information is subsequently stored in an INFO file, marked by the relation name, which has to be invoked (by the RELATE RESTORE command) each time a relational join, involving the two databases, is to be attempted. Frequently, a number of relates have to be invoked in order to create a map. Figure 25 is a diagram of the data flow during a relate operation and table 3 below is a listing of such a relate between table P4SF.PAT in INFO and SMALL in ORACLE.

Table 3 - Relate Listing (sample)

```
LIST P4SF POINTS P4SFNUM,P4FAI//CLASS,P4FAI//MATERIAL
             1
P4SFNUM                      =                 2953.00
P4FAI//CLASS                 = PESTLE
P4FAI//MATERIAL              = GABBRO
             2
P4SFNUM                      =                 1007.00
P4FAI//CLASS                 = BOWL
P4FAI//MATERIAL              = SANDSTONE
             3
P4SFNUM                      =                 2646.00
P4FAI//CLASS                 = CONICAL STONE
P4FAI//MATERIAL              = CHALK
             4
P4SFNUM                      =                 2653.00
P4FAI//CLASS                 = CONICAL STONE FRAG
P4FAI//MATERIAL              = CHALK
             5
P4SFNUM                      =                 2654.00
P4FAI//CLASS                 = BOWL
P4FAI//MATERIAL              = RW
             6
P4SFNUM                      =                 1096.00
P4FAI//CLASS                 = BEAD
P4FAI//MATERIAL              = DENTALIUM
```

A number of examples of the use of ARC/INFO and the

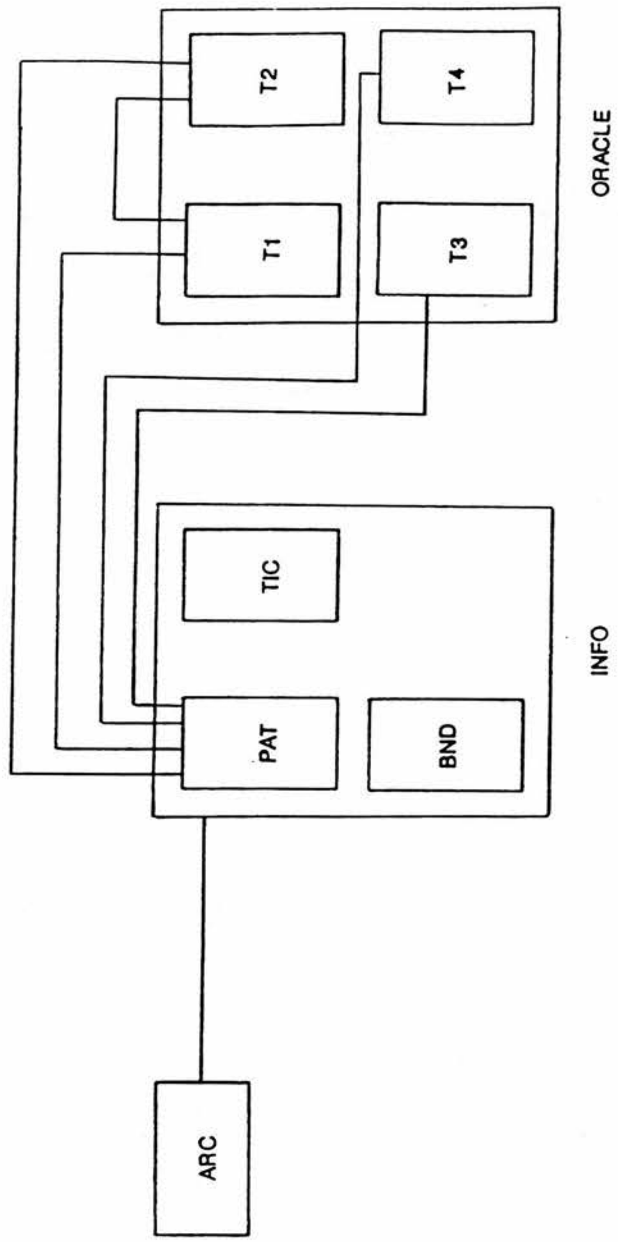


Fig. 25. Data Flow During the RELATE Operation

ORACLE interface for automation of site plans and mapping analysis of spatially referenced data for different locations within the site will be presented in this and the following chapter.

5.4 Range of Data to be Processed by a GIS

The archaeological topographic data required to be processed by the GIS include the following:

1. The excavation grid,
2. the section plans,
3. the plans of the individual features that have been excavated,
4. the general site plans in the following forms:
   (a) separated by stratigraphic layer, and
   (b) generalised by chronological period
5. the artifact scatters retrieved from the individual contexts again sorted by
   (a) stratigraphic layers, and
   (b) by the periods to which their context belongs.

In this particular study, however, the section plans have not been taken into account.

5.5 Digital Recording: Assumptions

Prior to the digital recording of the site and after having consulted the ground plans provided by the excavators, the following assumptions had to be taken into consideration:

1. The Kissonerga grid is placed in a NE direction and it is divided in 10 metre squares.

2. All record plans of the individual units within the site are referenced with regard to this particular grid.

3. The positioning of the grid poses the problem that it produces negative longitudinal references, since the X-axis coordinates are given in a descending order.

4. There are no true geographic coordinates given for the four corners of the grid.

5. The scale adopted for the large archive plans of the site is 1:50, while for the smaller individual plans the scale is either 1:10 or 1:20.

6. A two dimensional draughting policy has been adopted, as opposed to a 2.5 or 3-D one.

7. The information incorporated by the plans does not yet always correspond with that included in the

individual logs and records, and finally,

8. Each plan depicts a number of excavated units which do not all necessarily belong to the same period.

5.6 Digital Recording: Methodology

A step by step approach was adopted in order to sort out and solve each problem before digitizing the plans. This approach took the following form:

1. The orientation of the grid was changed by placing it in a NW direction. That involved a rotation of 90^0 (i.e. the X-axis became Y-axis and vice-versa). This action resulted in positive grid coordinates as opposed to the previous negative ones.

2. The grid was automatically generated on the computer with the aid of the GENERATE GRID command[1] in ARC/INFO. Distances were set to be measured in meters and the recording scale chosen was 1:50 to correspond to the scale at which the archive plans are drawn.

3. Each grid square was then copied into a separate file, thus constituting a "template" on which the excavated features falling within its boundaries would be drawn.

4. Additional copies of each template were made, one for each individual period present at the site.

5. The individual small plans were brought up-to-date by separating the units of the various chronological phases of the site. An additional effort was made to bring the information incorporated in the plans to a state where it would correspond to that of the logs and records (i.e. it was attempted to ensure that all units were assigned the correct unit number and that finds registered as belonging to a particular unit were clearly depicted on the plans). This was a complicated process which, unfortunately, was not entirely successful. The reasons for this are that it is a lengthy procedure and it would require the full-time involvement of a number of people who were not available at the time. A decision was made therefore to proceed with what was available to hand, but with a strong commitment by the Project to update the plans as the post-excavation analysis proceeds.

6. A few 1:10 and 1:20 plans were redrawn by the draughtsman at a scale of 1:50 to match the archive plans and were later digitized and checked for possible errors.

7. Small finds were also digitized as point coverages which would later be laid over the ground plans for visual reference. It has to be noted that during the digitizing process the computer automatically records the locational coordinates of each arc (i.e. line) and point, thus spatially referencing both features and finds[2].

8. The polygon labels assigned to the unit coverages were the actual unit numbers allocated by the excavators while those assigned to the point coverages were the small find number of each artifact recorded.

9. As stated above, during the process of digitizing the program automatically records the coordinates of each feature. This information is stored in a file in the INFO database. A file called .PAT records the perimeter and area measurements of each polygon or point (in the latter case, both measurements are set to 0) as well as their label number (stored as attribute <coverage name>-ID. However, ARC/INFO does not accept real numbers as IDs. The solution is to update the .PAT file by creating in it an additional attribute column which is set to accept real numbers. The labels can then be given their required values. From that point on it is this new column which is used to provide the identity of both polygons and points.

10. Thereafter, these coverages can be utilized individually or jointly, depending on which parts of the site one would like to plot. At least a master coverage of each period however should be developed for general viewing. This effect is achieved by using the MAPJOIN facility in ARC/INFO. The user is prompted to supply the names of the coverages to be joined and the computer automatically produces a new map incorporating all the grid squares chosen. At the same time, INFO prepares a new master .PAT file containing all the information present in the smaller .PAT files of the chosen coverages.

5.7 Preparing Coverages for Map Production

After completion of the digitizing, further preparatory steps had to be taken before meaningful thematic maps could be produced for display and analytical purposes. These steps were as follows:

1. Symbolism had to be chosen to distinguish the various classes of artifacts depicted on the plans. ARC/INFO provides several sets of such symbols in designated files each containing 100 symbols. In this case the default set was chosen mainly because the symbolism provided in that file was closest to the

original utilized by LAP in its previous publications (see Peltenburg et al, 1985a, "List of Symbols").

2. Once the symbol for each class of artifacts was chosen, the .PAT file had again to be updated by adding to it another attribute column containing a code number designating each artifact class. The default code number given by the computer following the creation of that column was 0. Consequently, that too had to be updated. There are two ways one can proceed in doing this. One, the most tedious, is to select each row of the .PAT file individually and change the code number accordingly. The second way is the fastest and easiest one but it poses some problems. Using RDBI-ORACLE, and most particularly the INFOORACLE command, the .PAT file can be transferred into ORACLE as an ORACLE table. Then, using a query like:

```
UPDATE <table name> SET
CODE= <code number>
WHERE P4-2423NUM {for example} IN
(SELECT SFNUMBER FROM SMALL
WHERE CLASS LIKE 'CONICAL STONE%');
```
[3]

the codes can be set to the desired values.

Table 4 presents a sample of a .PAT file before and after coding has been introduced to it.

Two more files have to be created in order to complete the process of adding symbolism to a coverage. First, a .CODE file has to be DEFINEd within INFO, containing three attributes:

(a) the <u>code</u>, distinguishing each artifact class,

(b) the <u>symbol</u>, containing the reference number of each

<u>Table 4. Adding codes to a .PAT table</u>

<u>Before</u>

AREA	PERIMETER	P4SF#	P4SF-ID	P4SFNUM
0	0	1	2953	2953
0	0	2	1007	1007
0	0	3	2646	2646
0	0	4	2653	2653
0	0	5	2654	2654
0	0	6	1096	1096
0	0	7	3175	3175
0	0	8	3176	3176
0	0	9	3177	3177
0	0	10	3172	3172
0	0	11	3138	3138
0	0	12	3200	3200
0	0	13	3234	3234

<u>After</u>

AREA	PERIMETER	P4SF#	P4SF-ID	P4SFNUM	TYPE
0	0	1	2953	2953	3
0	0	2	1007	1007	5
0	0	3	2646	2646	73
0	0	4	2653	2653	73
0	0	5	2654	2654	5
0	0	6	1096	1096	69
0	0	7	3175	3175	41
0	0	8	3176	3176	73
0	0	9	3177	3177	65
0	0	10	3172	3172	0
0	0	11	3138	3138	13
0	0	12	3200	3200	73
0	0	13	3234	3234	0

symbol chosen from the appropriate file, and

(c) the description, or definition, of each artifact class each symbol corresponds to (see table 5).

Table 5. Sample of .CODE file

TYPE	DESCRIPTION	SYMBOL
0		0
1	SOCK ST,CUP ST	2
5	BL,JR,CP,BS,MR	6
13	PESTLE	14
17	DENT SHELL	18
21	RUBBER	22
29	AX,ADZ,CHSL	30
33	DISC	34
37	QUERN	38

The second file is the .LEG (i.e legend) file to be created in a user file directory (i.e. outside the ARC/INFO environment). This file again contains the reference number of each symbol used in the coverage and the description of the artifact class it represents (see table 6). This file will be called during the creation of the legend on each map or plan compiled by the user.

3. In this analysis no particular shading was used to distinguish the various unit classes. The only exceptions were the shades assigned to depict grave types (see next chapter).

Table 6. Sample of .LEG file

```
.2
SOCKETED STONE
CUPPED STONE
.6
BOWL, JAR, CUP,
BASIN, MORTAR
.14
PESTLE
.18
DENTALIUM SHELL
.22
RUBBER
.30
AXE
ADZE
CHISEL
.34
DISC
.38
QUERN
```

As with symbols, ARC/INFO provides a default file with 100 shades to choose from. It also possesses facilities which enable the user to create new shade patterns, if desired. The process of attaching shade codes to the coverages is identical to that described for the symbols.

Following the processes described above the user is now able to write the programs (or files) which will create the desired maps. Examples of such map compilation files are given in Appendix IV and the resulting plans are included in volume II of this thesis.

Producing meaningful thematic maps is not the only facility offered by ARC/INFO. Its tables can also provide spatial information which, in addition, can be linked with the relevant ORACLE tables, as in the example in table 7 below.

TABLE 7. Sample linkage between ORACLE and INFO tables

UNIT	CLASS	AREA	PERIMETER
7	PIT	2.143	6.796
9	WALL	3.209	18.341
10	HEARTH	.461	3.586
11	PIT	.183	1.641
12	PIT	1.443	5.123
15	SURFACE (UNPAVED)	1.452	6.431
20	PIT	.709	3.431
21	STAKE - SCAPE	.002	.185
22	POSTHOLE	.064	.998
23	POSTHOLE	.024	.565
46	WALL	2.921	13.16
47	WALL	1.607	7.904
48	PIT	1.092	4.429
50	PIT	.406	2.563
58	PIT	.108	1.222
61	GENERAL	7.061	15.255
63	PIT	1.436	4.642
69	SURFACE (UNPAVED)	2.547	10.284

In this example, columns UNIT and CLASS are part of the ORACLE tables UNIT_LOG and UNIT_CLASS_CODE repectively, while columns AREA and PERIMETER were originally located in the INFO file P4.PAT. These items from P4.PAT were extracted from ARC/INFO using the INFOORACLE command and stored in ORACLE as a separate table. This could subsequently be queried in conjunction with the UNIT_LOG and UNIT_CLASS_CODE tables to produce the joint listing of attribute data and associated information from the digital map.

In addition to the above, some information stored in ARC/INFO can only be retrieved at the interactive command level, unless the programming language interface to the package is used to produce ASCII files containing the desired listings. Table 8 is a sample of such a file, named SF4.PNT. Using the UNGENERATE command at the ARC prompt it is possible, in this example, to retrieve the small find numbers of finds recovered from the Late Chalcolithic strata (period 4) along with their X,Y coordinates. This file can be used as it is or it can be loaded into ORACLE using the SQL*LOADER facility and then linked with table SMALL to provide spatial reports.

Table 8. Sample Small Find Coordinate Table

SFNUM	X-COORD	Y-COORD[4]
2953	229.898819	223.723129
1007	229.823624	226.982056
2646	228.620331	228.883072
2653	228.829224	228.302322
2654	228.766556	228.628204
1096	229.882111	228.749374
3175	229.823624	229.179718
3176	229.451767	229.313416
3177	229.602173	229.463837
3172	229.347321	229.062744
3138	229.079926	227.483414
3200	229.067368	227.888687
3234	229.259567	228.034912

END

5.8 2-D vs 2.5-D vs 3-D Representations

The two-dimensional draughting policy adopted by LAP presents the problem that it is not possible to convey visually the successive occupational phases within the site. To give an example, when a fairly well preserved building is drawn the plan incorporates its wall, floor, hearth, and, possibly, some other features located in its interior (e.g. pits, graves, etc.). The successive layers of fill excavated from within the building will not be shown. The case is similar for graves, pits and other units within the site. Nevertheless, ARC/INFO, can provide a solution and transform this 2-D approach into a 2.5-D one.

Alvey (1986; 1989) has developed a method of 2.5-D representation by providing a series of exploded views of an excavation which depict the succession of excavated layers in stratigraphic sequence. The alternative method used by GIS is the creation of new coverages to build the sequence (see figure 24, p. 10).

With the aid of the Harris matrix (Harris, E., 1989) the phasing (i.e. the succession of layers) of the site can be constructed[5]. This means that units will be assigned to individual successive layers extending over the whole site. Providing that every individual unit has been drawn during excavation, it could easily be selected by ARC/INFO and placed in a coverage depicting each one of these layers. For this, a query like the one presented below should be incorporated into an ARCPLOT file:

```
RESELECT <cover1> POLY ^STRATA1 WHERE -
STRLEVEL = 2
POLYGONS <cover1>
RESELECT <cover2> POLY ^STRATA2 WHERE -
STRLEVEL = 3
POLYGONS <cover2>
```

...and so on

To be executed, the query needs a number of base plans which will contain the various units excavated in each square. For example, square 23.22 may require ten such coverages (irrespective of period) to ensure that all units are present. In addition, an equal number of RELATEs will be required to enable RDBI-ORACLE to link the .PAT file of each coverage with table STRATA in ORACLE[6].

The methodology for conducting studies based on 2.5-D plans has already been explained and demonstrated elsewhere[7] and therefore it will not be repeated here.

Given the very shallow stratigraphy present, full 3-D representations are not very useful in intra-site applications in Cyprus. However, intra-site three-dimensional recording and analysis could be very useful in the study of deeply stratified tell-sites in the Middle East. For example, it could provide useful insights into the understanding and interpretation of post depositional processes. To provide but one example, consider the case where a very thick but also very shallow mud-brick wall is uncovered. The disproportionate measurements may be puzzling to the archaeologist and may remain unexplained for some time. A 3-D dimensional representation of the area, however, may reveal another unexplained accumulation of soil some distance away within the same level. The linking of the two findings is likely to lead to the conclusion that the located soil is a result of wall collapse (i.e the wall stood much higher than originally thought and at some time part of it deteriorated and fell). Moreover, some estimates regarding the height of the wall may thus ensue.

The depiction of the 3rd dimension is achieved through the use of Digital Terrain Models (DTMs). The definition given for a DTM is that of "a digital representation of a portion of the earth's surface" (Weibel, R. and Heller, M., 1991, p. 269).

The majority of DTMs today make use of either the rectangular grid (i.e. elevation matrix) data structure or the Triangulated Irregular Network (TIN) (see Weibel, R. and Heller, M., 1991). Both Raper and Kelk (1991), and Weibel and Keller (1991) have adequately detailed the conceptual differences between these two data structures. However, the difference of particular importance to archaeology is that TIN structures can easily incorporate structural features, while rectangular grids cannot (Weibel, R. and Heller, M., 1991). Since ARC/INFO utilizes TIN as its basis for 3-D implementations the criticism here will be concentrated on this particular approach.

TIN is a data structure which allows a surface to be represented as a series of non-overlapping contiguous triangular facets, the size and shape of which are both irregular. Each of the triangles contains information about its interior with reference to slope, area, and aspect, as well as identifying its topological relations to its neighbouring triangles (Marozas, B.A. and Zack, J.A., 1990).

The TIN data structure can offer a number of advantages for three-dimensional research and these have been well documented (e.g. ESRI, 1987; Marozas, B.A. and Zack, J.A., 1990; Raper, J., 1989; Raper, J.F and Kelk, B., 1991; Weibel, R. and Heller, M.; 1991). There are, however, a number of problems related to the reliability of the final model produced, with regard to the degree of inherent error.

One of the data sources for the TIN software package in ARC/INFO is a Digital Elevation Model (DEM). A DEM is "a digital array of regularly spaced points with X,Y, and Z values" (Marozas, B.A. and Zack, J.A., 1990, p.166). Since it is widely accepted that every base map to be used includes a certain degree of error, depending on its resolution (see Fisher, P.F., 1991), one can assume that, as a consequence, this error will also be transferred to the DEM. Other suitable data sources include contour and randomly distributed point data.

The TIN data structure is based on two fundamental concepts, generalization and simplification (Marozas, B.A. and Zack, J.A., 1990). In simplified terms, this means that the basic data format which is fed into the TIN is a lattice (i.e. a mesh of points which contain X,Y, and Z data for each point). The number of points should be kept at the minimum possible since ARC/INFO has a limit on the number it can store and manipulate (see ESRI, 1987). The programme will then perform an automatic triangulation based on a selection of the most significant lattice points (generalization stage). This kind of interpolation is likely to exaggerate any existing errors.

Marozas and Zack (1990) agree that the algorithms used by TIN in the creation of a 3-D surface model intend to provide the most accurate surface representation possible. Nevertheless, there is always a risk that the introduction and perpetuation of inherent errors can induce a considerably high level of bias which could limit the outcome of any potential study. In fact, there is no accurate 3-D GIS package today but there is hope that they will soon appear through general technological and scientific advances (Weibel, R. and Heller, M., 1991).

5.9 Issues to be Addressed in Site Mapping

There are a certain number of issues which have to be resolved when it comes to the mapping of any site. These issues are whether the final map productions will be in colour or in black and white only, and whether the computer is capable of replacing the draughtsman.

5.9.1 Monochrome vs colour maps

As a rule, both archaeological publishers and authors prefer monochrome map reproductions as opposed to colour ones. These are not only cheaper in terms of printing costs but they are also much easier to produce at the printing stage (Crummy, P., 1989). On the other hand, a dense monochrome ground plan incorporating dense symbolism is not only confusing but very often meaningless as well. Imagine, for example, map no. 23, in volume II, in black and white. Not only would no distinction be possible between the periods and their finds but certain areas of dense artifact and unit clustering would appear as black blots on the paper. The immediate solution would be to increase the scale considerably but the result would still be unsatisfactory, because there is no clear distinction between the outlines of the two periods or between their corresponding finds.

The debate could be a lengthy one and it is not intended to pursue it further in this thesis. However, some suggestions related to the problem are made in chapter VII. With regard to the Kissonerga excavation, monochrome reproductions are preferred whenever possible but the option is retained of using colour wherever this is thought to be advantageous in clarifying specific points of detail be made.

5.9.2 The Computer vs the Draughtsman

The graphics quality combined with the analytical facilities offered by an ever evolving range of computer hardware and software raises the question of whether or not the time has come to make the position of the archaeological draughtsman redundant.

The answer cannot be a straight yes or no. Arguments in favour of the computer can be made on the basis of three fundamental facts:

(a) That the graphics quality computers offer can be compared favourably to that produced by a draughtsman,
(b) that computers can store the digitized information accurately[8] and they can produce not only exact but multiple identical copies of it without any extra effort involved and,
(c) that the reproduced plans can be adjusted automatically to any desired scale, while the draughtsman would have to make laborious calculations in order to achieve the same result[9].

Nevertheless, it is preferable to argue that the computer should become a complementary instrument in the hands of the draughtsman rather than a replacement for his position.

It is very difficult to take a terminal with a digitizing tablet down into the trench, where machine-unfriendly conditions are prevalent. Whoever is involved with field archaeology must have witnessed the situations under which field draughtsmen often wcrk. In addition, many of the features included on a map are often easier drawn by hand rather than by the computer and the option to switch between the draughtsman and the computer should remain open for convenience.

5.10 Conclusion

In short, a GIS is more efficient than conventional draughting in capturing site plan information in the following ways. First, it transforms conventional plans to digital coverages thus promoting a more detailed study of the site plans in general. By attaching spatial references to all features incorporated in these plans it exercises control over any topographical bias introduced by manual draughting methods. Furthermore, the automated creation of plan overlays offers the potential for intra-site chronological and stratigraphic comparisons.

Finally, the major advantage of a GIS is its ability to generate new sets of data out of the ones already given. In practice this involves the creation of new individual coverages comprising features from a number of different cartographic layers.

The next chapter addresses a number of issues associated with the application of a GIS to archaeological analysis as well as providing a number of worked examples to demonstrate the advantages of a GIS approach.

CHAPTER V - Endnotes

[1] Commands related to ARC/INFO will hereafter be printed in capital letters. For a full discussion on the commands and the effects they have one should refer to the ARC/INFO and INFO manuals included in the bibliography.

[2] These references however are grid based, as already stated, because the true geographic coordinates of the grid were not available.

[3] The LIKE expression is used to shorten the query without losing any of the information stored in table SMALL (e.g. 'CONICAL STONE FRAG').

[4] Column headings have been provided by the author for improved clarity.

[5] See also Stratigraphy in next chapter, p. 196.

[6] Some remaining problems are discussed in section 8.4 in chapter VIII.

[7] See Papailiopoulos, D.: 1988, Archaeological Excavations at Lemba (Lakkous), Cyprus.

[8] Any topological errors that may be created by the draughtsman's hand and the person in charge of digitizing the coverage are halted at that stage. No more errors can be introduced afterwards.

[9] The full extent of the argument was presented at the Edinburgh BANEA conference (see bibliography).

CHAPTER VI

Implementing the System III: Analysis of Data

6.1 Introduction

In this chapter we will discuss the processes that take place at the post-excavational level with particular emphasis on the analysis of the primary archaeological data, as they have been recorded by the described in previous chapters system.

The major archaeological analytical requirements will be set out and attempts will be made to demonstrate the way in which the system can meet those requirements. The main effort will be placed on providing indicative examples rather than a full study of the site, since the post-excavation analysis is a lengthy process and the Project is still at its early stages. This fact poses significant problems for the data analyst, when it comes to providing firm results, since the chronology of the units and their stratigraphic sequence are still incomplete.

The basic attempt, as already stated in chapter V, will be to connect the ORACLE RDBMS with the ARC/INFO GIS via an interface called RDBI-ORACLE and facilitate bi-directional information exchange in an effort to benefit from the advantages offered by both systems (see section 5.2 in chapter V). Consequently, the results, where possible, will be presented both in tabular and graphic forms for improved clarity.

6.2 Archaeological Data Requirements

The primary data can be divided into three major information categories:

a) The finds, comprising small finds and pottery,

b) The excavated units,

c) The environmental data[1].

The answers sought by the archaeologists from studying the above listed material are multiple. Below is an attempt to classify the analytical requirements from each data category.

6.2.1 Finds

Finds can provide answers with regard to:

1. <u>Relative chronology and Date Calibration</u>: When a find dated to a particular chronological phase repeatedly occurs within certain deposits then its occurrence is regarded as indicative of the presence of that phase in the context. In the example provided in

table 9 and map no. 37 sherds of Red Polished vessels (RP) and their variants (RPV) are used to indicate the presence of period 5 (i.e. EBA) at various contexts in Kissonerga. Similarly, table 10 shows the occurrence of selected period 4 pottery types in their associated units.

Table 9 - Units Containing RP and RPV Pottery (sample)

```
SET LINESIZE 132
SET PAGESIZE 66
SPOOL RPVPOT
SELECT A.UNIT,C.CLASS,B.CLASS,
B.RIMCODE,B.CLCODE,B.WARE,B.SHERDNUM
FROM UNIT_LOG A,POTTERY B,
UNIT_CLASS_CODE C
WHERE
A.CLASSCODE=C.CLASSCODE AND
A.UNIT=B.UNIT AND
(A.WARE='RPV' OR A.WARE='RP' OR
A.WARE='RP?')
ORDER BY 1,6
/
SPOOL OFF
```

UNIT	CLASS	POT_CLASS	RIMCODE	CLCO	WARE	SHERDNUM
107	GENERAL	CLOSED BODY			RP	2
107	GENERAL	BODY?			RP	1
107	GENERAL	RIM	28		RP	2
1141	GENERAL	BODY?			RPV	26
1175	FILL	BODY?			RPV	20
1207	GENERAL	BASE		A	RPV	1
1207	GENERAL	CLOSED BODY			RPV	21
124	MISC	BODY?			RP	1
124	MISC	OPEN BODY			RP	2
125	PIT	CLOSED BODY			RP	3
140	FILL	OPEN BODY			RP	4
1412	GENERAL	BODY?			RPV	1
1417	GENERAL	OPEN BODY			RPV	3
1424	POSTHOLE	CLOSED BODY			RPV	1
1508	FLOOR (PAVED	OPEN BODY			RPV	2
159	PIT	OPEN BODY			RP	3

Table 10 - Selected Period 4 Pottery Ware Types (sample)

```
SELECT A.UNIT,C.CLASS,A.PERIOD,
B.CLASS,B.RIMCODE,B.CLCODE,
B.WARE,B.SHERDNUM
FROM UNIT_LOG A,POTTERY B,
UNIT_CLASS_CODE C
WHERE
A.UNIT=B.UNIT AND
A.CLASSCODE=C.CLASSCODE AND
(A.PERIOD='&PERIOD_A' OR A.PERIOD='&PERIOD_B' OR
A.PERIOD='&PERIOD_C' OR A.PERIOD='&PERIOD_D' OR
A.PERIOD='&PERIOD_E' OR A.PERIOD='&PERIOD_F' OR
A.PERIOD='&PERIOD_G' OR A.PERIOD='&PERIOD_H' OR
A.PERIOD='&PERIOD_I' OR A.PERIOD='&PERIOD_J') AND
(B.WARE='&WARE_1' OR B.WARE='&WARE_2' OR
B.WARE='&WARE_3' OR B.WARE='&WARE_4' OR B.WARE='&WARE_5'
OR B.WARE='&WARE_6' OR B.WARE='&WARE_7'
OR B.WARE='&WARE_8' OR B.WARE='&WARE_9'
OR B.WARE='&WARE_10' OR B.WARE='&WARE-11'
OR B.WARE='&WARE_12' OR B.WARE='&WARE_13'
OR B.WARE='&WARE_14' OR B.WARE='&WARE_15'
OR B.WARE='&WARE_16')
ORDER BY 1,3,7


Enter value for period_a: 4
Enter value for ware_1: RW
Enter value for ware_2: BTW
Enter value for ware_3: RWMC
Enter value for ware_4: CW
```

UNIT	CLASS	PERI	CLASS	RIMCO	CLCO	WARE	SHERDNUM
1	BUILDING	4	OPEN BODY			RWMC	20
1	BUILDING	4	CLOSED BODY			RWMC	7
1	BUILDING	4	BASE		B	RWMC	1
10	HEARTH	4	BODY?			RWMC	1
101	PIT	4	RIM	28		RWMC	4
101	PIT	4	BODY?			RWMC	12
101	PIT	4	OPEN BODY			RWMC	13
101	PIT	4	CLOSED BODY			RWMC	2
102	PIT	4	OPEN BODY			RWMC	2
103	BASIN	4	RIM	28		RWMC	1
105	PIT	4	RIM	28		BTW	2
105	PIT	4	OPEN BODY			BTW	4
105	PIT	4	BODY?			CW	7
105	PIT	4	BODY?			RWMC	5
105	PIT	4	CLOSED BODY			RWMC	2
105	PIT	4	OPEN BODY			RWMC	26
105	PIT	4	HANDLE		H	RWMC	1
105	PIT	4	RIM	2		RWMC	1
105	PIT	4	RIM	3		RWMC	1

2. Typology: Artifacts can be divided into typological sub-groups by studying their measurements, material and manufacturing technology. When there is evidence of the presence of a group of particular finds (e.g. over five) that demonstrate similar measurements, material, or manufacture (or any combination of the three) then they are classified as representatives of a certain type[2]. Below, table 11, is a list of type 1 conical stones[3]. Note that in the present example typology has been based solely on manufacture and not on measurements or material. Manufacturing details of an artifact category can promote further typological distinctions. Table 12 shows how specific ceramic handle types relate to the various pottery wares within the site.

Table 11 - Type 1 Conical Stones

SFNUM	CLASS	TYPE	MATERIAL	LENG	WIDTH	THICKNESS
582	CONICAL STONE	1	CHALK	4.7	1.9	1.8
586	CONICAL STONE	1	CHALK	4.6	3.1	3
587	CONICAL STONE	1	REEF LIMESTONE	5	2.7	2.6
588	CONICAL STONE	1	CHALK	3.6	2.5	2.2
602	CONICAL STONE	1	CHALK	3.6	2.8	2.6
603	CONICAL STONE	1	CHALK	3.1	3.8	3.7
604	CONICAL STONE	1	REEF LIMESTONE	3.2	2.1	1.5
1069	CONICAL STONE	1	SANDSTONE	7.7	6.5	6.1
1108	CONICAL STONE	1	CHALK	7.1	6.5	6

Table 12 - Pottery Handle Types (sample)

```
BREAK ON CLCODE SKIP 2
TTITLE LEFT 'LAP 90' RIGHT 'Page ' SQL.PNO -
SKIP CENTER 'TYPES OF HANDLES ORDERED BY CLCODE' SKIP 2
COMPUTE SUM OF SHERDNUM ON CLCODE
SELECT CLASS,CLCODE,WARE,UNIT,SHERDNUM FROM POTTERY
WHERE CLASS='HANDLE'
ORDER BY CLCODE,WARE
```

```
LAP 90                                       Page        1
        TYPES OF HANDLES ORDERED BY CLCODE

CLASS           CLCO WARE    UNIT    SHERDNUM
--------------- ---- ------- ------- --------
HANDLE          BB   "X"     1207           1
                ****                 --------
                sum                         1


HANDLE          C    "X"     707            1
HANDLE               ?       1207           1
HANDLE               RMP     2053           1
HANDLE               RMP     383            1
                ****                 --------
                sum                         4


HANDLE          CC   "X"     626            1
HANDLE               "X"     559            1
HANDLE               "X"     326            1
HANDLE               RMP     117            1
HANDLE               RMP     559            1
HANDLE               RWMC    1014           1
HANDLE               RWMC    559            1
                ****                 --------
                sum                         7
```

3. <u>Distribution</u>: The distribution of artifacts within the limits of the site can provide answers with regard to:

a) the function of certain units (i.e. pinpoint flint knapping activity in a particular location),

b) types of activity taking place at the site in general (e.g. pendant and stone tool manufacturing),

c) the types of activities undertaken by the inhabitants both within and outside the site, indicated by the classes of material present,

d) craft specialization, as in the case of building 3 where there is indication of the presence of tools belonging to a single craftsman, possibly a carpenter[4].

e) the nature of the material culture, especially when studying the finds in their entirety. The material culture itself demonstrates the society's level of art and craftmanship, its degree of cultural complexity and, perhaps, the type of social organization represented,

f) the economy or types of economy these people were practising. Then one can infer whether the local community was a pastoral, or agricultural society, or practised some kind of mixed economy[5].

The examples provided are maps 30-33, 38 and 40. These are six small-find distribution maps aiming to show some of the potential offered by the use of RDBI-ORACLE, the ARC/INFO - ORACLE interface.

Map 40 shows the distribution of small finds in the upper field. In this case the system has selected the total of the finds registered on the plans.

For map 30 a certain category of finds, the figurines, was chosen to demonstrate the ability of the interface to choose a certain class of artifacts. Note the concentration in unit 1015.

Map 31 shows not only the possibility of being able to select a certain group of artifacts, but also the ability of the program to distinguish a certain sub-category of that group such as, in this case, type 2 conical stones[6]. Moreover, another map, no. 38, shows the distribution of conical stones of all types in period 4. Again as in map 31 the overwhelming majority appears to be concentrated in building 3 thus possibly associating conical stones with commodities or commodity storage areas.

The fact that building 3 was a central (possibly communal) structure for the accumulation of commodities is also demonstrated by map no. 33 which shows that an enormous number of artifacts (when compared with other individual structures) were incorporated within its walls. Worth mentioning is a group of stone tools all bearing a "mark" and thought to belong to a craftsman, possibly a carpenter[7].

Finally, LAP's publication policy (at least in LAP

Vol. 1), was to assign a single symbol for a number of artifact classes[8]. Map 32 shows such a symbol being used to indicate the presence of axes, adzes, or chisels in various contexts. Only in this example, the program made the distinction by choosing the relevant symbol to demonstrate the presence of axes only. Note two areas of axe concentrations, one in square 23.20 near the centre and the other in 24.18 at the top middle part.

4. Imports and Exchange Mechanisms: These are identified by the presence of items foreign in construction or of material not indigenous to the region. It requires parallel studies of other sites and regions to establish the origin of those artifacts and also the distribution mechanism, explaining their presence at the given locality.

An interesting aspect of such a study would be to establish the nature of material or commodity that was exchanged in return for those imports, but, as already said, this requires studies at a larger scale, involving inter-site comparisons. In our case, we will concentrate on imports only and maps 34 and 35 depict the occurrence of faience, a material not only foreign to Kissonerga but also to Cyprus as a whole, since its origins can be traced to Egypt (Peltenburg, E.J., 1988a).

Maps 34-35 show the areas in which the presence of faience was encountered. Two observations can immediately be made. One is that the faience found was all in the form of beads and second, that a number of those beads were located in only three graves (map no. 35): Gr538 (one bead), Gr541 (3 beads) and Gr546 (eight beads). The single occurrence of faience in the Middle Chalcolithic (map 34) could be explained as an intrusion from the upper levels since it was located in a disturbed context.

6.2.2 Units

The study of units can clarify questions with regard to:

1. Relative chronology and date calibration: This can be achieved by studying the architectural features, their associated deposits and their stratigraphic links with other units. Map 28 shows the occurrence of the largest buildings excavated at Kissonerga. All attributed to the "age of prosperity" - the Middle Chalcolithic - they are by far the largest in prehistoric Cyprus (Peltenburg, E.J., 1988a). Both B3 and B206 are thought of as communal(?) central storage

areas (Croft, P., in Peltenburg, E.J. and Project Members, 1986, Peltenburg, E.J., 1988a) leaving only B2 as the largest habitational unit at the excavated part of the site. Below is a list of their associated deposits[9] (table 13).

Table 13 - Contents of buildings 2, and 3 (sample)

Building 2 - Contents

```
SELECT A.UNIT,C.CLASS,B.SFNUMBER,B.CLASS,
B.TYPE,B.MATERIAL FROM
UNIT_LOG A,SMALL B,
UNIT_CLASS_CODE C,
SFUNIT D
WHERE
A.CLASSCODE=C.CLASSCODE AND
B.SFNUMBER=D.SFNUMBER AND
A.UNIT=D.UNIT AND
A.UNIT='2'
UNION
SELECT A.UNIT,C.CLASS,B.SFNUMBER,B.CLASS,
B.TYPE,B.MATERIAL FROM
UNIT_LOG A,SMALL B,
UNIT_CLASS_CODE C,
SFUNIT D, PART_OF E
WHERE A.CLASSCODE=C.CLASSCODE AND
B.SFNUMBER=D.SFNUMBER AND
A.UNIT=D.UNIT AND
A.UNIT=E.UNIT AND
E.PARTOF='2'
ORDER BY 1,3,4,5
```

UNIT	CLASS	SFNUM	CLASS	TYPE	MATERIAL
2	BUILDING	341	LID		MICA SANDSTONE
2	BUILDING	342	LID		CALCARENITE
2	BUILDING	343	STOPPER		REEF LIMESTONE
34	WALL	340	PHALLUS		CHALK
41	HEARTH	620	ANVIL		GABBRO

Building 3 - Contents

```
SELECT A.UNIT,C.CLASS,B.SFNUMBER,B.CLASS,
B.TYPE,B.MATERIAL FROM
UNIT_LOG A,SMALL B,
UNIT_CLASS_CODE C,
SFUNIT D
WHERE
A.CLASSCODE=C.CLASSCODE AND
B.SFNUMBER=D.SFNUMBER AND
A.UNIT=D.UNIT AND
A.UNIT='3'
UNION
SELECT A.UNIT,C.CLASS,B.SFNUMBER,B.CLASS,
B.TYPE,B.MATERIAL FROM
UNIT_LOG A,SMALL B,
UNIT_CLASS_CODE C,
SFUNIT D, PART_OF E
WHERE A.CLASSCODE=C.CLASSCODE AND
B.SFNUMBER=D.SFNUMBER AND
A.UNIT=D.UNIT AND
A.UNIT=E.UNIT AND
E.PARTOF='3'
ORDER BY 1,3,4,5
```

UNIT	CLASS	SFNUM	CLASS	TYPE	MATERIAL
52	FILL	378	CONICAL STONE		CHALK
52	FILL	388	CONICAL STONE		CHALK
52	FILL	392	CONICAL STONE		CALCARENITE
52	FILL	393	ADZE	2	BASALT
52	FILL	397	POINT		BONE
52	FILL	398	MISC		TOOTH
54	POTSPREAD	1352	HOLEMOUTH JAR		CPW
54	POTSPREAD	2022	STORAGE JAR	1E	SW
905	GENERAL	1220	POUNDER	1	LIMESTONE
905	GENERAL	1221	ADZE FRAG	1	BASALT
905	GENERAL	1222	POUNDER	2	DIABASE
905	GENERAL	1222	RUBBING STONE		DIABASE
905	GENERAL	1223	ADZE	1.2	PYROXENE ANDESITE
905	GENERAL	1226	PESTLE	3	CALCARENITE
905	GENERAL	1227	SHELL		SHELL
905	GENERAL	1228	POUNDER	1	CHERT
905	GENERAL	1229	CUPPED STONE	3	CALCARENITE
905	GENERAL	2954	CONICAL STONE		CHALK
905	GENERAL	2955	CONICAL STONE		CHALK
905	GENERAL	2956	CONICAL STONE		CHALK
905	GENERAL	2957	PAINTED PEBBLE		DENSE CHALK
905	GENERAL	2958	WORKED PEBBLE		CHERT
905	GENERAL	2959	CONICAL STONE		CHALK

2. Function and Levels of Occupation: In conjunction with the study of artifact distribution within structures, the study of other units (or features) incorporated by a structure, can provide insights with regard to the function of the main buildings. That was particularly true in the case of building 3 and the secondary rectangular buildings of period 3, as described by Peltenburg (1990, pers. comm.) and shown in maps 24 and 33.

Table 14 provides the contents of another two "specialized" units, those of the ceremonial pit 1015 and building 994 in which the pit was located.

Table 14 - Contents of 1015 and 994 (sample)

Unit 1015 - Contents

UNIT	CLASS	SFNUM	CLASS	TYPE	MATERIAL
1015	PIT	1428	POINT FRAG		BONE
1015	PIT	1442	FIGURINE		RW
1015	PIT	1443	FIGURINE FRAG		RW
1015	PIT	1444	BUCKET		RW
1015	PIT	1445	BOWL		RW
1015	PIT	1446	CULT VESSEL		RW
1015	PIT	1447	SPINDLE WHORL FRAG		CLAY
1015	PIT	1448	PEBBLE		CHALK
1015	PIT	1449	ANTHROPOMORPHIC POT		RW
1015	PIT	1450	TRITON SHELL		SHELL
1015	PIT	1451	FIGURINE		RW

Building 994 - Contents

UNIT	CLASS	SFNUM	CLASS	TYPE	MATERIAL
994	BUILDING	1413	BOWL		RMP
994	BUILDING	1414	MACEHEAD		GABBRO
994	BUILDING	1415	POT LID		CHALK

3. Typology: As with artifacts, measurements, construction techniques and individual architectural features can provide the basis for a subcategorization of units into distinctive types as, for example, the rectangular and circular buildings of the MChal (see maps 24 and 25 respectively). The function of the rectangular structures is thought to have been an ancillary one to the circular buildings, as their contents suggest[10]. Another example is the typology developed for the excavated graves[11] (see table 15 below and maps 8-22).

Table 15 - Grave types

TYPE	DESCRIPTION
0	PITHOS / LARNAX BURIAL
1	SCOOP / SURFACE BURIAL
2	PIT GRAVE LEMBA I
3	PIT GRAVE LEMBA II
4	SINGLE CHAMBER TOMB
5	BOTTLE SHAPED SHAFT GRAVE
6	MULTIPLE CHAMBER TOMB

Maps 8-10 are distribution plans of the grave types present in each period. The upper field plan bears no distinction of periods since these have not yet been formally identified by the excavators and therefore, it offers limited information. By way of contrast, he plans of periods 3 and 4, in the lower field, are more specific.

Only four of the excavated graves have been attributed to period 3 (tentative chronology). Of those, one belongs to type 1, two to type 2, and one - the most elaborate in terms of finds (Peltenburg, E., 1992) - to type 3 (Baxevani, E. and Papailiopoulos, D., 1992).

Period 4 incorporates the whole range of the evolution of grave architecture at Kissonerga, from shallow scoop burials (type 1) to the sophisticated double chamber tomb (type 6). All in all, there are two type 0 graves, fifteen of type 1, eighteen type 2, six type 3, twelve type 4, and one type 6 - located almost at the centre of the excavated area (Baxevani, E. and Papailiopoulos, D., 1992).

Full details of the preliminary analysis conducted with the aid of KAIS on the graves and their contents have been given elsewhere[12] and it is not our purpose to repeat them at this point.

The map sequence 11-22 provides the unit numbers of the individual graves along with their unshaded outlines in an attempt to highlight more the architectural details, as much as it is possible in a two dimensional representation. Some of the "awkward" shapes that result (e.g. grave 525) are due to the fact that some of the grave features, in the master site plans, are blocked by those of other units. This is one of the disadvantages of having a 2-D draughting policy, a problem which has already been discussed in chapter V and we will refer to again in the following chapter VIII.

4. Distribution and Spatial Organisation: The study of the spatial arrangement of units can provide useful insights about the evolution of the site through space and, ideally, time. The study of unit clustering and the associations among the structures themselves and among the structures and the site, both in each particular period and generally, would help considerably to bridge those few remaining gaps in the stratigraphic sequence of the site.

Maps 26 and 27 present such an example. Between the square buildings 1295 and 1165, on one side, and circular building 2, on the other, there is a surface consisting of cobblestones which Peltenburg (1990, pers. comm.) has identified as a track dividing the large (round) building sector, in the West, from that of the smaller (also incorporating the rectangular) structures of the Middle Chalcolithic in the East. This assumption however does not provide for the presence of yet another small rectangular building (B1000) to the east of building 2. Furthermore, the track appears to be blocking the entrance of building 1165, thus suggesting that its construction antedates the occupation of the rectilinear structures (Peltenburg, E., 1990, pers.comm.). Further evidence in support of that latter fact is provided by the results of the preliminary stratigraphic sequence incorporated in the database (see results of table strata below in table 16).

Table 16 - Stratigraphic links of B2, track and square buildings

```
SELECT * FROM STRATA
WHERE UNIT=2  OR UNIT=1295
OR UNIT=1165 OR UNIT=35 OR
UNIT=1000
ORDER BY STRLEVEL,UNIT
```

UNIT	ABOVE	STRLEVEL
1000	2	2
1000	1168	2
1000	1477	2
35	1161	5
35	2075	5
35	2091	5
2	636	10

Table 16 (cont'd)

2	2114	10
1295	1103	12
1295	1483	12
1295	1487	12
1295	2080	12
1295	2083	12
1295	2086	12
1295	2100	12
1295	2122	12
1165	2073	20
1165	2124	20
1165	2042	20
1165	2061	20
1165	2067	20
1165	2072	20

5. Stratigraphy: There are several ways of presenting the various strata graphically, as explained in chapter V. Nevertheless, in the given situation of two-dimensional, multiple layer planning the best solution found was to employ the Boast and Chapman (1990) SQL queries[13] to, at least, establish the stratigraphic succession in a tabular form. Their study was commissioned by the Museum of London and the University College London in an effort to develop a system to simulate the Harris Matrix graphically. This system would enable future researchers to automatically reassess the stratigraphy of a given site. These queries, modified according to the parameters present in the Kissonerga RDBMS, are presented below in table 17 along with a sample of the results they have produced[14] (table 18).

Table 17 - Construction queries for table STRATA

STRATADD.SQL

This query is used to fill the values of attributes Unit and Above in table STRATA. The information is acquired from tables ABOVE and BELOW which are incorporated in the excavation's database.

```
INSERT INTO STRATA (UNIT,ABOVE)
SELECT UNIT,ABOVE FROM ABOVE
UNION
SELECT BELOW,UNIT FROM BELOW
WHERE UNIT NOT IN
(SELECT ABOVE FROM ABOVE)
/
```

STR.SQL

These macros update table STRATA by searching the stratigraphic succession and by setting the contexts to the appropriate level. The first macro initialises the process by setting unit 0 (the ploughsoil) to level 0. The second macro is continuously applied, each time set to a lower level, until there are no more units to be updated.

Macro 1

```
UPDATE STRATA SET
STRLEVEL=0
WHERE UNIT=0
/
```

Macro 2

```
UPDATE STRATA SET
STRLEVEL=11
WHERE UNIT IN
(SELECT ABOVE FROM STRATA
WHERE STRLEVEL=11-1)
/
```

STRUP.SQL

This query searches for faults in the stratigraphic succession. Once such a fault is encountered it automatically adds a value of 9000 to the original value of attribute Above thus making it easily distinguished. These faults should be corrected manually and then the process must be resumed from the beginning.

STRUP.SQL (cont'd)

```
UPDATE STRATA SET ABOVE=ABOVE+9000
WHERE ABOVE IN
(SELECT UNIT FROM STRATA
WHERE STRLEVEL=
(SELECT MAX(STRLEVEL) FROM STRATA)
INTERSECT
SELECT ABOVE FROM STRATA
WHERE STRLEVEL <
(SELECT MAX(STRLEVEL) FROM STRATA)) AND STRLEVEL=
(SELECT MAX(STRLEVEL) FROM STRATA)
/
```

Table 18 - Preliminary results of table STRATA

STRATA.LIS - Stratigraphic Sequence (sample)

UNIT	ABOVE	STRLEVEL
0	942	0
2116	2125	1
2125	2126	2
2068	2069	3
2069	1300	4
2054	1469	5
2075	2079	6
2076	2084	7
2093	2109	8
2119	2120	9
2120	2135	10
2137	695	11
2105	2110	12
2143	2144	13
2099	2089	14
972	831	15
718	1286	16
1286	1276	17
2142	1103	18
1292	1192	19
1165	2124	20
1418	1341	32[15]
96	9004	33

STRMIS.LIS - False Stratigraphy

UNIT	ABOVE	STRLEVEL
1328	10161	6
1461	10328	8
2023	11020	9
1416	10228	10
108	9206	32
112	9206	32
228	9004	32
986	9004	32
995	9004	32
96	9004	33
206	9002	33
745	9206	33
873	9206	33
1186	10187	33
1331	9206	33

In generic terms, the Harris Matrix is based on four Laws, namely the Law of Superposition, the Law of Original Horizontality, the Law of Original Continuity, and the Law of Stratigraphic Succession (see Harris, E., 1989). In practice, the matrix recognizes three types of relationships between units, namely (a) "the units have no direct stratigraphic connection", (b) "they are in superposition", and (c) "the units are correlated as parts of a once-whole deposit or feature interface" (Harris, E., 1989, p. 36). In colloquial archaeological language, the relationships between units are represented by the terms no relationship, above, and same as[16].

The Boast and Chapman queries deal fully with the second type of unit relationship and partially with the first, but totally ignore the third case (see Boast, R. and Chapman, D., 1991).

The application of the Boast and Chapman method by KAIS is as follows: The first step is to treat the same as relationships in an effort to minimize unit relationship redundancy in the Matrix, even more than Harris originally suggested, by amalgamating the related units. To give an example, suppose that two parts of an once-complete floor, now cut by a foundation trench, are excavated. During the course of excavation a unit number has been assigned to one part of the floor, another to the trench, and a third to the other part of the floor. Once it is established by excavation that the two floor pieces are part of a once single unit, one of the unit numbers originally assigned is cancelled and both parts are thereafter referred to by one single number, thus eliminating the same as relationship.

The no relationship case is not treated at all in this thesis, since the Boast and Chapman method does not adequately deal with the subject yet and the unrelated units do not comprise the focus of the present study[17].

The present method, however, builds the

superposition sequence and examines whether there are any errors in the recording and if so, indicates the units involved.

B994 was chosen to be presented here as a worked example (map no. 29) because of the problems it poses in its association with a number of pits excavated in its interior. Two of those pits were pit 1015 (see discussion in chapter II) and pit 1225, containing a large number of fire-cracked stones and broken pottery similar to that of unit 1015 (Peltenburg, E. and Project Members, 1989). Both pits indicate that some form of ritual had taken place at some point in the history of the site, most probably a "closing" ceremony; following that, the site was abandoned (Peltenburg, E. and Project Members, 1989). Nevertheless, B994 was once more occupied in the years following the ceremony and its inhabitants appear to have been apprehensive of the presence of the ceremonial area beneath their feet (Peltenburg, E. and Project Members, 1989).

The superposition sequence provided by STRATA (table 19) shows that pits 1201, 1202 and 1205 are located in level 2, higher than the level of the floor (unit 983) of building 994. It must therefore be assumed that their construction postdates that of pits

1225 and 1015 as well as the foundations of building 994. Pits 1015 and 1225, on the other hand, are situated below B994 (located at level 3) and presumably its floor (unit 983). Although table ABOVE contains no entry for unit 983, to calibrate our assumption, nevertheless we must take it for granted since Peltenburg states that both pits were securely sealed by the floor of building 994 (Peltenburg and Project Members, 1989).

Table 19 - Stratigraphy within B994

UNIT	ABOVE	STRLEVEL
1201	983	2
1202	983	2
1205	983	2
994	4	3
994	1015	3
994	1225	3
994	1284	3
994	1383	3
994	2085	3
943	4	4

6. Overlays: It has been stated since the outset of this thesis that one of the problems at Kissonerga is the extensive recycling of building material in antiquity (see chapter II). By using computer generated period overlays we hope to establish the degree of material reuse in certain localities. Moreover, we make an effort to identify the origin of intrusive materials

especially in areas where the stratigraphy has been identified as problematic, as, for example, in the lowest stratum of building 3.

Finally, by comparing, or rather by overlaying, ground plans of the successive occupational phases we can identify certain patterns of human occupation and, subsequently, social organization. We can also follow the evolution of the site as a settlement and a burial ground by filling in the gaps and hence, establish a continuity in the record. A series of maps (i.e. maps 5-7, map 23, 39 and 36) provide good examples of the afore-mentioned studies as they have been carried out by the Project.

Maps 5-7 were produced in order to provide a visual reference with regard to the exact location of units which are discussed in this chapter. The features depicted are attributed to the same period (with the exception of the upper field) but this does not necessarily imply that they also belong to the same stratigraphic level. Each period had many sub-phases of building activity and occupation, some of which have already been distinguished in this discussion.

Map 23 is a two colour overlay of Periods 3 and 4. The settlement shift to the SW in Period 4 is clearly visible as it is also the effort made to erect buildings in areas unoccupied by structures of the preceding Period 3 (with the exception of B3 which is clearly cut through the walls of Period 3 building 1103). This probably had ensured two things: (a) Less construction effort, since the builders would not have to demolish pre-existing foundations to lay new ones, and (b) ready access to recyclable material (e.g. stones) from the remaining rubble of Period 3.

A question remains unanswered however, as to why this preference to the SW is evident, since that is right on the banks of the Argakin tis Skotinis (the perennial river next to which the site was located). Erosion by the river had resulted in unstable ground in that section of the site and there is evidence that efforts had been repeatedly made to stabilise the shifting areas (Peltenburg, E., 1990, pers. comm.).

Map 39 is a complex overlay of periods 3 and 4. Similar to map 23, it also incorporates the artifacts of each period in an attempt to depict clusters of small finds in each phase within the site.

Finally, map 36 is an example of a structural evolution with regard to the construction of the circular buildings.

Throughout the Middle Chalcolithic circular buildings incorporated a pair of ridges radiating from the hearth towards the eastern side, thus separating a certain section of the building floor from the rest of the structure (see B1547), probably with the intention that it should serve as a ritual area (Peltenburg, E., 1991, pers. comm.). This area, as the record shows, was kept clear of artifacts (Peltenburg, E., 1991, pers. comm.).

In the Late Chalcolithic those ridges disappear. Nevertheless, a closer study of the distribution of finds within period 4 structures shows that a certain area in the east of each building does not contain almost anything at all as if the ridges were still there. It is believed that some other form of partition might have existed to mark the area (Peltenburg, E., 1991, pers. comm.)

6.2.3 Environmental Data

The study of the environmental data gathered can provide information associated with:

1. Diet: By locating the presence of consumable materials in the site.

2. <u>Possible reconstruction of past landscapes</u>: By studying the presence of domesticated plants in conjunction with the carrying capacity of the soil as established by the geological study of the immediate environs of the site.

3. The combination of the geological study along with the material present at the site could lead to the establishment of the activity limits of the site. The results of this study can then be placed against those of other neighbouring areas to identify settlement "territories".

4. The results of the horticultural analysis along with those that will be produced by the study of animal bones excavated will provide some indication of the site's carrying capacity, in terms of the number of inhabitants.

Figure 26 shows a statistical representation of the items discovered through flotation thus far, and the proportions in which they occurred. Much of the work on the environmental material is not yet completed and therefore, it is difficult to draw any conclusions at this point.

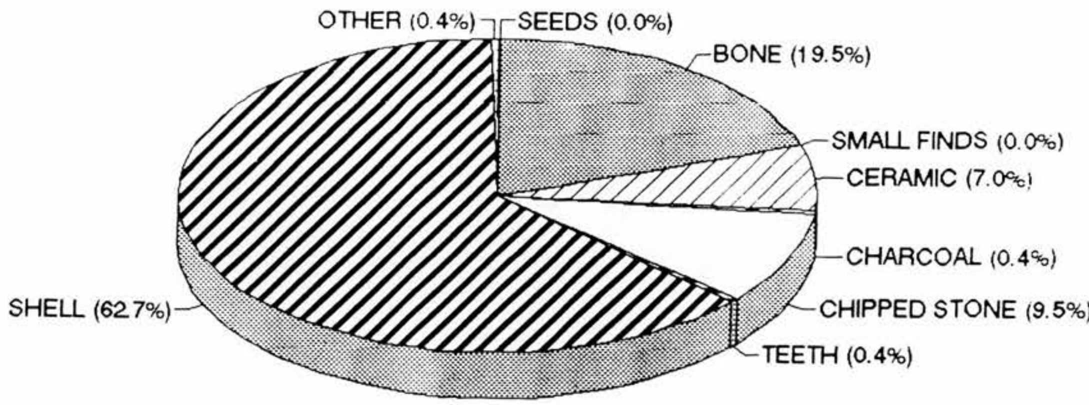


Fig. 26. Flotation statistics

6.3 Time as a Categorical Variable

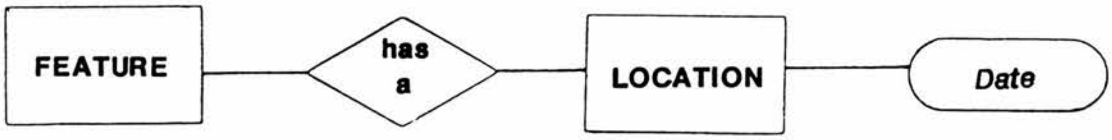
An important issue to be assessed is that of the temporal aspect of data stored in a GIS. Aangeenbrug (1991) has argued that current GIS have very little capacity to handle temporal data and that "models of spatial succession are too general if they exist at all" (Aangeenbrug, R.T., 1991, p. 105). Healey (1991) also sees incorporation of the temporal aspect in a database as a thing for the future. To make matters even worse, time is normally visualized as a forward progression, while in archaeology the view is exactly the opposite; that is, excavation starts from the uppermost and newest strata and gradually progresses towards the lowest and oldest ones (Stine, R.S. and Lanter, D.P., 1990). In other words, archaeology works in a backward chronological sequence.

Stine and Lanter (1990) have conducted research to examine ways in which the time aspect could be incorporated into an archaeological database in order to facilitate spatio-temporal queries. The conclusion of this study was to propose Armstrong's conceptual model as a first step towards the use of time as a categorical variable.

Armstrong (1988) has introduced the concept of the "time stamp attribute". In other words, he maintains that each geographic feature within a GIS could be assigned a time tag which in turn would enable the tracking of any changes in that feature across time. To illustrate this notion he has provided the following equation:

$$Duration = Time(n) - Time(n-1)$$

In terms of database modelling, this can be illustrated as follows:



The KAIS database also relates entities <u>Unit Log</u>

(i.e. Feature) with Location and Period. Admittedly, this constitutes only a very crude classification of time since an archaeological period may incorporate several centuries. Subperiods may be distinguished based on a number of variables (e.g. C^{14} dates, artifact analyses etc.) but that is not always possible.

Limited as it might appear, the use of the time component within a GIS could still provide some useful results. For example, one could map the occurrence of attributes between two time slices (e.g. period 3 and period 4). The overlaying of these single period attribute maps could generate a sequence which in turn could allow the monitoring of spatial changes over time, either at an intra-site or an inter-site level (Stine, S.R. and Lanter, D.P., 1990).

Stine and Lanter conclude that the use of time stamps on archaeological entities "could be used to view the chronological history of a particular artifact or feature [and as a result], the temporal aspects of areas of interest could be traced from prehistoric to historic to the date of excavation" (Stine, R.S. and Lanter, D.P., 1990, p. 87).

To be able to refine the above described treatment of the time aspect, further research is needed because, as Langran (1989) has pointed out, current GIS systems are unable to handle space, time, and spatio-temporal analysis in an efficient manner. Instead, priority has to be given to one of the dimensions over the others.

6.4 Conclusion

The addition of the ARC/INFO GIS to the core archaeological recording and analysis system, built around the ORACLE RDBMS, will not only strengthen the analytical power of the system as a whole but it can also have an impact in offering direct solutions to existing problems.

The use of a GIS will add spatial referencing to the site, feature and find records, thus introducing a more permanent and accurate recording, as opposed to the temporary one offered by conventional recording systems and planning methods.

The advantage lies in the fact that the natural shift of the control points of the archaeological grid will be of no consequence whatsoever, since the grid could be easily re-established based on the true geographic coordinates which will have been recorded by the GIS. Moreover, archaeological drawings will not be affected by the expansion or shrinking of drawing material (i.e. paper) since the plans will be permanently and accurately stored in the computer and could be readily reproduced.

The ability of ARC/INFO to RESELECT automatically features and finds and store them in separate coverages according to their chronological and stratigraphic sequence, combined with the creation of cover overlays, can facilitate a rigorous and accurate reconstruction of the stratigraphic sequence of the site.

In addition to the afore mentioned, ARC/INFO also offers the possibility of isolating individual features of interest, by ZOOMing into the general plans, thus enabling their closer and more detailed study.

The full integration of ARC/INFO with ORACLE and the ability to exchange information freely between the two database systems can reveal and, at the same time, codify potential data inconsistencies present in both the archival material and the site plans. In addition to that, the graphic representation of the excavated layers and their contents could considerably enhance the interpreting capabilities of the archaeologists by enabling a visual testing of theories related to the interpretation of the site.

The use of the standardized, query language offered by SQL can provide for the convenient construction, modification, and execution of both standard and ad hoc queries and macros which, in turn, will enable a thorough, rapid, and efficient examination of the captured information.

Finally, the ease with which plans and maps are created, updated, and plotted could save considerable time and financial resources during map production and publication[18].

Thus far we have discussed the method for the development of an archaeological GIS based information system and we have seen some examples of how such a system can be employed in an excavation. The next chapter will be an effort to discuss the potential that computers offer in assisting the publication of the results of the excavation.

Chapter VI - Endnotes

[1] The reasons for excluding the animal bones from the database have been given in chapter IV.

[2] It has to be stressed however, that very often typology is developed for ease of reference for the researcher and it is not always indicative of deliberate categorization on behalf of the ancient craftsman.

[3] Typology belongs to Dr Carolyn Elliott, ground stone tool industry specialist of LAP.

[4] See Elliott, C. in Peltenburg, E.J. and Project Members, 1987.

[5] However, one has to keep in mind that there are bound to be types of activity which are not archaeologically recoverable.

[6] For a definition of types see Elliott, C., in Peltenburg et al 1985a.

[7] We do regret the fact that we are unable to provide a plan depicting this tool assemblage since the artifacts in discussion have not yet been registered on the excavation's plans.

[8] See Peltenburg, E.J. et al, 1985a, "Key to Figures".

[9] The small find record contains no entries for building 206 although it did contain a number of pottery finds (Croft, P., in Peltenburg, E.J. and Project Members, 1986).

[10] See chapter II and Peltenburg, E.J. et al, 1988, Peltenburg, E.J., 1989b.

[11] The grave typology has been developed by Ms Karen Nicklasson for the Lemba graves (see Peltenburg, E.J. et al, 1985a) and Ms Evi Baxevani for the Kissonerga graves (see Baxevani, E. and Papailiopoulos, D., 1992), both grave specialists of LAP.

[12] See Baxevani, E. and Papailiopoulos, D., 1992 (included in Appendix VI).

[13] The publication however contains a number of errors. The correct versions of the faulty queries are given in Appendix V.

[14] Since the phasing of the site is incomplete and the final dating of several units is still pending, these results should be regarded only as preliminary. Official (and final) announcement will be made in the forthcoming publication of the excavation.

[15] Note the sudden gap in the sequence from level 20 to level 32. It is an indication of the presence of faulty stratigraphic associations.

[16] Moreover, the KAIS database also provides for the recording of associations found between features which are part of a larger unit (see chapter IV).

[17] For the process of treating such relationships, see Harris, E., 1989.

[18] Also see chapter VII.

CHAPTER VII

Computer Assisted Archaeological Publications

7.1. Introduction

The final phase of the excavation process is the publication of the activities that took place around and within the site, the results produced as a consequence of those activities and the secondary analyses conducted on the excavated finds.

Publication is not merely a scientific obligation but primarily it is a moral one (Barker, P., 1989, Grinsell, L., Rahtz, P., Price-Williams, D., 1974). A site has been excavated (and hence destroyed[1]): all finds have been removed and dispersed (e.g. to museums, laboratories, even dumps) and all evidence has vanished from the ground. The person responsible for these activities bear the obligation, as the only witness, to present both to the public and the various institutions (or government bodies) (i) what was actually done at the site; (ii) what was found, (where, and in what state) and finally, (iii) their interpretation of the function of the site in a local, regional, national or even international context.

7.2 The Nature of Archaeological Publications

Before we proceed to discuss the contribution of an automated system in enhancing the scope and improving the quality of an archaeological publication, certain points have to be made.

The first point is that an archaeological publication addresses a certain readership. Many debates have taken place in the past, and still continue to do so, in an effort to establish who are the groups of people who constitute that readership. Ideally, three categories of people are addressed:

(a) Fellow archaeologists, historians and researchers with a general interest in the specific excavation.
(b) Specialists with a need for very particular, detailed and specialised information, and
(c) The general public, this being laymen with a relatively casual interest in archaeology; non-specialist students and schoolchildren (Barker, P., 1989).

Most publications manage, to a greater or lesser extent, to oblige the first two categories but they tend to neglect the last (and to some, the most important) category. The use of highly specialised terminology is one element to be blamed for this fact and it is so widespread that even prominent archaeologists themselves raise complaints, longing with nostalgia for the general, descriptive and highly personal style prevalent in reports of the 18th and 19th centuries (Hodder, I., 1989). The other element is the stark presentation of facts with the absence of any form of personal interpretation with regard to their general importance for, or indication of their contribution to the enhancement of knowledge.

The second point is the form in which archaeological publications are presented. Again, there are three types of publication format:

a) The preliminary (or interim) reports,

b) The actual publication and

c) The archive[2]

7.2.1 Preliminary (Interim) Reports

When an excavation extends to more than one season, it is customary (and sometimes required) that interim reports for each such season should be produced and distributed to a variety of people and institutions or published in an established bulletin or periodical. These reports have a multi-purpose function. One objective is to provide information about progress that has been achieved at the site, and to present any problems which may have arisen, with the intention of obtaining valuable feedback from sources external to the excavation (i.e. other scholars). Another role is to convey a general idea of the accomplishments of the season to the volunteers who have worked at the site. This is partly in appreciation of their efforts, but at the same time the aim is also to attract them, along with potential newcomers, to volunteer for the next season as well (Grinsell, L., Rahtz, P., Price-Williams, D., 1974). Finally, such reports aim to satisfy the financial contributors by demonstrating the good made of their money, and concurrently to act as a fund raiser for operations in the immediate future.

In order to achieve such a wide scope, preliminary reports should be kept in a concise but informative format, enthusiastic in style and free of any excessively scientific terminology, so that they will convey the message without causing any fatigue to the reader. Another factor in favour of a short interim report is the low cost of its production and publication.

7.2.2 The Actual Publication of the Site

This takes the form of a book, or, in extreme cases, a series of volumes (e.g. Jericho, Thera, Pompeii, etc.). The contents really depend on the editorial decisions of the author or authors of the publication. Libraries contain a number of what could be called "exemplary" publications but also a greater number of prime examples of how not to publish a site.

Normally, the contents should comprise the following general[3] components:

a) Introduction: Clearly defining the reasons and aims for which the excavation was conducted.
b) History of the Site: What was known about the site from any possible source such as historic accounts, previous surveys, or information from the local inhabitants.
c) The Site and its Environs: Site location, characteristics, description of its immediate environs, geomorphological and climatological studies, including an account of processes (natural or man-induced) that possibly have affected or continue to affect the site.
d) The Excavation: Descriptions of units and finds, the chronological and stratigraphic sequence at the site and most important, section drawings, context plans, artefact drawings and context and artefact photographs.
e) Specialist Reports: These may include palaeoenvironmental studies, such as palaeobotany and palaeozoology, pollen analysis, wood identification

studies, metal analysis and so on. With the advances of science and the theoretical justification of New Archaeology (Binford, L.R., 1983, Clarke, D., 1973) we could have a situation where one or more specialist reports could be produced for every single find category.

f) Synthesis: For many, this is the most important part of publication of an excavation (Barker, P., 1989, Grinsell, L., Rahtz, P., Price-Williams, D., 1974, Hodder, I., 1989, Jakobs, K. and Kleefeld, K.D., 1991, Tilley, C., 1989). In this section, besides offering direct conclusions on the immediate history and function of the excavated site, the author should face the challenge of placing the site in a wider geographical and chronological context. Inferences on social, economic, political and religious structures should be made, based on the evidence, and then discussed in a regional or, if possible, even wider context, thus contributing to the overall task of reconstructing the past.

g) Inventory of Finds: Often exceedingly lengthy lists of material recovered from the site. Ideally, all should be listed but many tend to be selective when it comes to the publication[4].

7.2.3 The Archive

This is a Pandora's box for all those not directly associated with the excavation. It contains all excavated material, published and unpublished, along with all comments and initial interpretations made during the course of the dig. When placed at the disposal of the public (as should be the case) it constitutes a primitive form of publication (Barker, P., 1989).

The third and final point regarding archaeological publications is that they should be completed within a certain time period. Preliminary reports should be published as quickly as possible but at the same time should fulfil the purposes outlined above. The optimum time for the main publication to come forward is approximately one year from the completion of the excavation (Barker, P., 1989) but that is far from the norm. In some Scandinavian countries the rules state that if a publication has not been completed within five years, then all material from the excavation (including the archive) becomes public property (Grinsell, L., Rahtz, P., Price-Williams, D., 1974). Cyprus, with which we are concerned in this instance, has imposed the rule that if an excavation has not been published, or at least there is no proof that the publication has substantially progressed, no further permit will be issued to the person(s) concerned for any form of archaeological activity on the island (Thomas, G., 1991, pers. com.). Rapid publication therefore, is to the benefit of all parties concerned.

7.3 The Automated System as a Means for Assisting Publication

The evolution of archaeological techniques of excavation, recording, and analysis of data has led to a flood of information becoming available for publication (Barker, P., 1989, Crummy, P., 1987, Grinsell, L., Rahtz, P., Price-Williams, D., 1974). In addition to that, intensive land development has put pressure on governments, institutions and consequently, archaeologists to increase the range and the scale of their operations. As a result, the number of rescue excavations has also been on the increase, producing ever more data to be handled and eventually published (Carver, M.O.H., 1985, Grinsell, L., Rahtz, P., Price-Williams, D., 1974, Papailiopoulos, D., 1989). The situation of having too much material to include in a publication is worsened by steeply rising publication costs. These make large reports uneconomical (Crummy, P., 1987) as well as hard to compile, since the time limits are very restricted and contributors have a tendency to fund excavations, but to become much less generous when it comes to financing an archaeological publication (Barker, P., 1989, Grinsell, L., Rahtz, P., Price-Williams, D., 1974, Tilley, C., 1989).

But the size and price of a publication is only one aspect to be considered. The other is to satisfy the readership. Generally speaking, there are two ways of presenting the excavated material from a site: a) by period and b) by category. There is also a third approach, to attempt an amalgam of the previous two ways of presenting an excavation. In this case, however, the results can be catastrophic in terms of text consistency and therefore, we will not take it into consideration.

In the first case above, the excavated material is described and discussed as a whole and placed in the context of the period to which it belongs. We can have, for example, a presentation of tools, architecture, figurines and so on, of the Early Chalcolithic period. The same is done for all possible other periods present in the site. The second method is to select a specific category of finds, for example architecture, and describe their characteristics and evolution throughout the chronological sequence identified.

It is evident that some of the readers of the report will wish to avail themselves of the first approach, others of the second. But in a publication one can follow only one of these methods. Consequently, some readers will be displeased with the selected approach (Papailiopoulos, D., 1989).

Given this situation, we will proceed to suggest how an automated system can provide solutions to the problems that can arise.

As has been stated in the previous chapters, we have at our disposal a powerful database to handle our data and a GIS to map the site and conduct the spatial analyses. The word processing software can handle the production of the text. There are a growing number of publishers who do accept (and some even demand) documents on floppy disks, and who possess the appropriate computer packages to handle these texts and prepare them for final publication (Girdwood, A., 1988). Although this practice can cut costs substantially, if one considers the amount of time and effort saved when comparing the use of a computer instead of a typewriter, it is still not enough to substantially decrease the overall expenditure of a publication (Sutton, A., 1986). The alternative given is the use of a desk-top publishing package. Although it requires more time to master and employ it, this produces documents in camera-ready form (including plates and graphs[5]), which can go directly for printing (Crummy, P., 1987). The costs of acquiring a desk-top publisher of relatively high standard are substantially outweighed by the reduction of the price charged by printers to produce the final volume of the publication. To improve things even more, the costs of running a second printing are also dramatically reduced.

For smaller works, such as the writing and printing of interim reports, an integrated system such as KAIS provides an efficient platform for rapid results. Reports can be produced using either ORACLE's SQL*PLUS facility, or the more sophisticated SQL*Reportwriter, regarded by some as more user-friendly, since it is menu driven (Perry, J.T. and Lateer, J.G., 1989). In SQL*Reportwriter one can override the fairly standard format produced by SQL*PLUS and re-design or re-arrange the layout of data on a page, achieving an optimum text presentation. To make matters even better, SQL*Reportwriter does not hinder the creation and execution of queries nor the performance of any type of arithmetic functions and statistics which are also available in SQL*PLUS. The list files produced by both SQL*PLUS and SQL*Reportwriter are in ASCII format and from there they can be transferred to an ordinary document file in either the word processor, or the desk-top publisher, so that they can then be incorporated in the text to be published.

ORACLE's spreadsheet, SQL*Calc, is another very useful tool for producing statistical output for reports. Being fully integrated with the ORACLE RDBMS, as well as menu driven, it provides the fastest means of interfacing with the database to extract the required information (ORACLE Corporation, 1986). It also produces basic graphs for visual display of the results. The files created are once again in ASCII format which can be directly incorporated in the text in the word processor. Tables created in SQL*Calc can also be exported in LOTUS 1-2-3 format and therefore can be transferred to other spreadsheets like, for example, QUATTRO which offer a much better graphic quality.

Maps and plans can be accurately reproduced through ARC/INFO. There is no need to pre-determine the scale in which the final plans will be plotted since that can be arranged through the map programming language (i.e. the MAPSCALE command in ARCPLOT). With the RESELECT command one can also have specified sections of the master plan drawn separately at a larger scale for greater clarity. Since the output remains unchanged for as many copies as necessary, colour becomes no obstacle for use in the publication if one of the two following options are taken:

The first option is to use the ARC/INFO PLOTSIF command, to convert an ESRI plotfile to a SIF (i.e. Standard Interchange Format) file. Then, by using a Scitex graphics system composite film negatives can be produced to be incorporated in the publication.

The second option is to use the POSTSCRIPT command. ESRI describes the POSTSCRIPT capabilities as follows:

> "The POSTSCRIPT command converts an ESRI plot file into an industry standard PostScript page description file. This adds a range of advanced capabilities to cartographic output from ARC/INFO, including overposting of symbols, automatic color separation, use of high resolution typeset fonts for text, and so on. The resulting PostScript file can be printed on any device with a PostScript interpreter (e.g. Apple Laser Writer or a Linotype Linotronic Imagesetter). The PostScript file can be used to generate a monochrome representation of a plot file. The POSTSCRIPT command can also be used to generate a set of composite plates ready for a color printing process. Each plate will be output as a different PostScript file. PostScript files can also be incorporated directly into electronic page layout and publishing systems" (ESRI, 1989b).

Otherwise, if a colour plan were to be produced by using conventional printing methods it would substantially increase the costs of the publication (Crummy, P., 1987). Furthermore, if the maps and plans were plotted on transparent plastic sheets[6] (such as Mylar) instead of regular paper one would have the advantage of working with accurate plans since these sheets neither shrink nor expand as paper so often does.

Having described some methods for reducing publication costs through the use of computer facilities (further proposals are made in the next chapter) we can proceed to look upon some new and, if one wishes, radical ideas for reducing costs even more.

Both Hodder (1989) and Tilley (1989) have heavily criticised the format in which archaeological publications are presented today. They both feel that they have become too "scientific" with endless lists of excavated material, and analyses put forward in a highly specialised jargon. Concluding, they make the same remark that the effort should be concentrated on developing the synthesis in as wide a context as possible, and that some other method should be found of presenting the details. Some countries have already issued guidelines with regard to this, as for example in France, where it has become an official policy that the emphasis should be placed on synthesizing the results of an excavation. As for the finds and their treatment, that has been left to the discretion and the conscience of the excavators (Gaubet, M., 1989, pers. com.).

Attempts have been made in the past to publish the finds inventories in microfiche form in a pocket at the back of the publication volume. It has, however, proved to be an inefficient method since those microfiches tend to disappear or are even deliberately taken out by the libraries in which the volumes are stored (Peltenburg, E.J., 1989, pers. com.). In such a case, consulting a publication becomes an unproductive task for the individual researcher.

Wilcock (1981) has stated that data stored on a hard disk constitutes, according to copyright law, a form of publication. Talab (1986) has added to this statement by clarifying that databases are treated by law as literary works, while generated programmes may fall under the auspices of laws protecting films and videotapes. Computer scanned photographs and digitized maps and plans[7] are protected by the laws applying to works of art (Vitoria, M., 1986).

It is therefore proposed that, henceforth, the synthesis should be published as a book and the lists and analyses should be stored on a hard disk, or floppy disks (eventually all to be substituted by the safer and more durable WORM disks), copies of which can be handed in to the appropriate institutions along with instructions for the retrieval of the information[8]. In case someone needs the information but lacks the training or facilities to operate the necessary retrieval procedures, they will be able to put forward an application stating their requirements, and printouts of the results will be forwarded at a minimum cost to cover the system querying operations. These relatively small costs will be compensated by the low price of the original publication.

Other advantages of having the data stored on disk and made publicly available are: firstly that the archive is as error free as possible, due to the possibility of thorough cross-checking of stored material that the computer offers; secondly that the data can become widely available for consultation and further analysis, (the results of which can again be stored on disk); and thirdly, that it can be made available for a wide range of educational purposes. Lastly, but most important of all, through such a facility, the excavators become effectively accountable for their interpretations and conclusions. In such a case Lavell will have been justified for saying that:

> "I take it as axiomatic that the whole point of spending millions of pounds yearly on digging and publishing archaeological sites is to improve the sum of human knowledge: that all this information has some future purpose, and is not just being collected like stamps or engine numbers" (Lavell, C., 1986, p.75)

Jakobs and Kleefeld have gone one step further in proposing that a central databank should be set up, to which an unlimited number of terminals can be linked, thus forming (in an optimal situation) an international public domain archaeological network.

Computers in use on any excavation would also be able to be linked to the databank so the results of the day's excavation could be downloaded to become instantly available for public consultation (Jakobs, K., and Kleefeld, K.D., 1991). The only problem they have identified in such a process is that an unscrupulous scholar may appear at a conference presenting preliminary results obtained by someone else. Apart from the legal implications (violation of copyright law, as has been previously explained), the problem also has a strong moral aspect. This is where the solution lies, according to the authors: If the results are so widely publicized no-one will be able to present what will be public property as his/her own work. Moreover, any attempt to do so would also jeopardize the process of effective and reliable information exchange.

In summarizing this point, we can do no better than refer to Goethe who once wrote, in another context but with great relevance still, that:

> "There is no such thing as a patriotic[8] art or a patriotic science. Both art and science belong, like every higher good, to all the world and can be fostered only by the free flow of mutual influence among all contemporaries, with constant regard for all we have and know of the past (Ceram, C.W., 1980, p. v[10]).

7.4 Conclusion

Two concluding cautionary notes are required on the publication of archaeological excavations.

The first is that the computer should not be regarded as a panacea. The quality of the input will in large measure determine the eventual value of the output. If the data are inconsistent, the results produced will be also and, of course, what has not been inserted cannot be retrieved or generated afterwards. Furthermore, it goes without saying that, if an excavation has been conducted in an ineffective manner, computerizing the results will not improve matters. In fact, it may even worsen the situation, unless the excavator identifies the sources of error and makes an effort to correct them. As Weizenbaum once wrote:

> "...if a bad idea is to be converted into a good one, the source of its weakness must be discovered and repaired. A person falling into a manhole is rarely helped by making it possible for him to fall faster or more efficiently" (Weizenbaum, J., 1976, p. 35).

The second word of caution regards copyright licences. Besides the burden of obtaining the necessary permissions for the literary and illustrative parts of the publication one will have also to ensure that software user and site licenses are also in order. There is no advantage in using the programmes if that use cannot subsequently be reported.

Chapter VII - Endnotes

[1] It has to be repeated again that excavation is a destructive process. Once the evidence has been removed it can only be artificially replaced via a communicative medium (i.e. diagram, plan, etc.) but not physically in all its microscopic fidelity.

[2] Why the archive is considered a form of publication will be discussed further on in this chapter.

[3] It may be thought necessary to break these general components into several individual chapters, especially if a lot has to be said for any one of them.

[4] From this list of publication components the obvious has been ommited such as, for example, acknowledgements to assistants and contributors, both financial and institutional; references and bibliography.

[5] For a more thorough discussion on graphics and plates and how they can be handled by the computer see the discussion of "Future Proposals" in the next chapter.

[6] Many plotters do accept this type of sheet and there is a requirement for special pens that are capable of drawing on such a surface.

[7] Note should be taken that the law refers to digitized versions of one's own work and not the work of others. Digitizing and then reproducing material created by other persons or agencies without their prior consent constitutes a serious breach of copyright law.

[8] Implications will arise however because the individual institutions may not have the appropriate software and hardware to retrieve the required information (Sutton, 1986). Software licences will also be a considerable problem. For a full discussion of these implications as well as of possible solutions see next chapter.

[9] In this instance read personal or individual.

[10] Reprinted from: GOETHE, W.J.: 1805, Winckelmann und sein Jahrhundert.

CHAPTER VIII

Conclusion

8.1 Introduction

This thesis would not be complete without an evaluation of the system in use (i.e. KAIS), a list of its limitations, and finally a summary of proposals for future improvements deriving from our experience of recording the excavation.

8.2 Evaluation of the System

Immediately following the introduction of KAIS to the Kissonerga excavation the benefits of computerisation became evident. Below follows a general categorisation of the advantages offered by KAIS as it stands today. Nevertheless, it is only natural that as research continues the following list will grow, since new areas of application will be revealed.

The general advantages offered by KAIS in its present state are as follows:

1. Data Consistency: By organising the individual logs in a coherent manner and by monitoring updates to ensure data consistency in all areas of excavation

recording.

2. Standardisation: By the introduction of codes and keywords KAIS provides a meaningful categorisation of the retrieved archaeological information, ensuring that no data will be ignored during the final analysis.

3. Accuracy: By spatially referencing the whole excavation and by controlling plan updates as well as providing automated data searches as opposed to manual ones.

4. Information Centralisation: By centrally collecting and interrelating information otherwise located in a number of sources (e.g. other computer programmes, individual notes, files and so on).

5. Data Security: By controlling access to the stored information at all levels, such as consultation, updating, copying, etc.

6. Accelerated Data Processing: By speeding up the recording, retrieval and analysis of the captured data.

7. Objectivity: By concentrating on the quantified recording of the data, thus restricting the introduction of subjective interpretations (these can

be filed separately as individual notes).

8. Prevention of Accidental Introduction of Errors: By preventing any further manual data manipulation. Consequently, the possibility of accidentally introducing new errors (for example, during a redrawing of the plans) are minimized.

9. Improved Excavation Recording Methods: By introducing a new way of thinking. Excavation strategies are developed with regard to the database format used by the system. The result of this process is an efficient and flexible excavation record which subsequently can be analysed, both within and outside the database.

10. Data Dissemination: By making information readily available at any level during the excavation, post-excavation, or at the publication stage.

11. System Integration: By ensuring the free flow of information among the various programmes and modules comprised by KAIS.

12. Data Portability and Availability: By facilitating compact data storage on floppy disks or on a hard disk as opposed to a number of filing cabinets. This ensures

that the total data load will accompany the excavators in the field as well as in the laboratory.

13. Improved Publication: Primary analysis can be conducted at an accelerated rate, allowing the possibility for more and better preliminary reports as well as the execution of further studies which will enrich the general understanding of the excavated site and its material.

14. A Permanent and Expandable Record: By (a) allowing information retrieval in various forms, (b) providing the means for re-establishing the exact location of the excavated material in a possible future attempt to resume excavations at the site, and (c) making possible to link the information provided with that from other sites for a "global" approach.

15. Accountability: As already said, by providing only the facts about the site, the system leaves open the possibility for a re-interpretation of the synthesis provided by the initial excavator.

16. Improved Archaeology: By making the information widely available and easily accessible, it enables researchers to concentrate more on developing theories rather than classifying and publishing raw data.

Having listed the major advantages offered by KAIS to archaeological work, it is worth isolating and emphasizing the potential advantages that the GIS element offers in enhancing the intra-site approach.

8.2.1 The GIS Element within the System

As has already been stated, there is no adequate body of current literature on the use of a GIS at the intra-site level. However, the present application has helped to demonstrate that the potential of a GIS based archaeological system is very considerable.

At the management level, a GIS could be employed at a very early stage to produce a survey study of the area which will be excavated. Surface finds can be plotted in an attempt to establish the limits of the potential site and can be incorporated in the report accompanying the application for an excavation license, together with a map of the property proposed for expropriation. This will assist officials in assessing more objectively the limits of the area to be given for excavation.

The next stage would be to map the exact location of possible underground powerlines, water pipes, etc.

in order to avoid any possible damage to them. An assessment study of processes that might have affected the site itself, such as, for example, agricultural practices, land consolidations, and erosion processes would also be possible.

Of pure archaeological interest would be to establish the limits of possible previous archaeological activities within or near the site to be excavated, as well as, determining whether some of the surface finds have been washed down from other nearby located sites. This often the case in Cyprus.

At the application level, the GIS can be utilized from the beginning of the excavation (i.e. initial fieldwalking and grid laying). Surface artifact scatter densities can be plotted and examined in order to locate the "site within the site". That is, to determine the areas under which archaeological features are most likely to be located. This will determine both the orientation and extent of the grid to be laid, and the central point from which excavation will commence.

Besides the recording and primary analysis of the excavation which have been documented in this volume, there are a number of other intra-site archaeological activities which could benefit from the use of a GIS.

For example, distribution patterns of artifacts could be plotted in an effort to assess the function of buildings. The same method applied to pottery could provide some insights into the dating of the units and could also be used as one of the calibrating methods while developing the stratigraphic sequence of the site (see Harris, E., 1989).

Intra-site spatial analysis could also be facilitated in an attempt to assess the spatio-temporal aspect of cultures within the site. The methodology for conducting such studies is already well documented in the relevant literature (e.g. Hodder, I. and Orton, C., 1976; Hietala, H.J., 1984; Huggett, J. and Cooper, M.A., 1991; Whallon, R., 1974).

Environmental information could also be plotted by mapping the distribution of faunal and floral remains in the site. Such a study could provide new insights into subsistence patterns and would also help to model the exploitation of resources and possibly reconstruct the economy of the site.

The results obtained thus far by the system have altered many of the traditional approaches that archaeologists have had, both towards their data and their excavation methods. Improved excavation strategies and data collection and analysis have, as a result, fostered new theoretical approaches, to aid archaeologists in deciphering the prolific prehistoric record of Cyprus.

More specifically for the Kissonerga excavation and in addition to the above the contribution of KAIS can be summarized in the words of the director of the excavation:

> "The system has speeded up things enormously and helped (and will continue to generate more approaches) in several ways including:
>
> 1. Several specialists are now able to make inquiries concerning contextual associations in space and through time. Previously, this was only possible at a very superficial level because of the vast amount of data and the limited time at their disposal.
>
> 2. Leading from 1) is the increased control and hence credibility of the functional analysis of units, and changes in the use of similar units through time. {This has} important social implications.
>
> 3. By examining metric data for tools and containers, for example, we can begin to talk about suspected development of standardization and specialization; and by plotting these increases, correlate them with periods and spaces/buildings. Again, {this has} important social implications.
>
> 4. Relating the emergence of different tool types with changing fauna/flora assemblages provides new insights into Mediterranean island economic intensification patterns. Previously, {this was} impossible to do because of so much data"
>
> (Peltenburg, E., 1992, pers. comm.)

8.3 Limitations of the System

The limitations that the system presents can be divided into two categories: a) Those present due to our research strategy and b) those imposed by the hardware and software used in the research. The first category can be classified under the heading "Tasks still to be performed" and are incorporated in the section on future proposals further on in this chapter. The limitations comprising the second category are listed below:

1. ARC/INFO <cover>-ID attribute columns cannot accept decimal labels.

2. Key ARC/INFO files (such as .BND, .AAT, .TIC and .PAT) cannot be efficiently exchanged with the ORACLE database. If changes are made on one of those files in ORACLE and the file is then imported back into ARC/INFO the internal file format will be drastically altered and INFO will lose all pointers linking a coverage with its supporting files.

3. RDBI-ORACLE can read one row of data from a single table at a time when used in an ARC RESELECT statement. Therefore, instead of conducting an interactive relational join, the user is forced to create ORACLE

views comprising synthesized data from several tables to be read by ARC/INFO. This limitation will, however, disappear in ARC/INFO V.6.0 with the introduction of database cursors.

4. The RELATE command is not operable from within INFO, thus making updates requiring a relational join with ORACLE impossible.

5. The ARC command UNGENERATE accesses only the <cover>-ID column and not the one containing the calculated real values incorporating the actual small find and unit numbers. This means that whenever a table of point coordinates is required manual updating has to take place.

6. Primary key updates into ORACLE should cascade throughout the database structure. Ideally, one such change should suffice and the system should execute all the rest. Fortunately, this problem in relational database engineering is approaching solution in relation to new releases of the SQL query language standard (Healey, R.G., 1991, pers. comm.).

7. ARC/INFO PC is not as robust a programme as is its mainframe version. Unfortunately this is a common problem with most GISs in the market at present.

8. The Boast and Chapman method adopted for the IBM does not provide the graphic output (i.e. the stratigraphic sequence diagram) that it normally does when applied on APPLE computers. That is because on the APPLE application, ORACLE is graphically interfaced with HyperCard. In addition to that, the system also makes use of SuperCard which enables the definition of complex graphic structures which eventually will simulate the Harris Matrix. Such a compatible method has not yet been developed for an IBM application.

9. The 2-D draughting policy in effect restricts both the efficient graphic presentation and stratigraphic conceptualisation of the excavated layers.

10. Training is absolutely vital to ensure the safe operation of KAIS. Nevertheless, some time will be needed until the majority of LAP's personnel reach the desirable competence level.

11. The economics associated with the system and its operation, although they have been kept at a minimum, are still a considerable burden on the budget of the excavation.

12. There is always the possibility that LAP's

computerised archives will pose some problems for the institutions to which they will be presented (e.g. Department of Antiquities, Cyprus, or the National Museum of Cyprus). Lack of computer facilities and training will again be the reasons for these problems but due to the high level of flexibility offered by KAIS (i.e. independent software modules, ability to create output in ASCII format etc.) these can be overcome.

8.4 Summary of Future Proposals

Keeping in mind LAP's remaining publication requirements as well as their planned future archaeological activities, a number of suggestions follow in an attempt to further the improvements already introduced by the use of KAIS.

With regard to the database, there is a need for more tables to be included in the initial structure. The immediate requirement is for tables to incorporate the samples, animal bones, human remains (both, skeletal data and those collected by the oral biologist), sections, pottery pattern analysis information, C^{14} analyses, and conservation data.

Improvements to existing tables are also desirable, and in particular, attribute Unit should be converted to type number. Only then will it be possible for it to be sorted numerically (a very helpful procedure when it comes to the analysis of the data), or to be efficiently grouped (by employing numeric functions, as, for example to select the unit numbers falling between number 500 and 600 (i.e. the graves). Moreover, a unit number should be assigned to the lowest stratum of the excavation (i.e. the bedrock). It should be a large number (e.g. 6000) in order to make it easily distinguished from the rest of the units. The result of this action will be a more efficient STRATA table which will clearly mark the end of the stratigraphic sequence at the site. Otherwise, this is denoted by a number of units which are recorded as being located above nothing (i.e one cannot be sure that a null entry in column Above marks the lowest stratum or a missing stratigraphic link).

Table SMALL should incorporate a column for attribute Multiple. There, the secondary functions of a tool will be recorded instead of repeating it as a separate entry, as the practice has been until now.

By adding attribute Site as part of the primary key to every table incorporated in the database, the structure of the database is automatically transformed from a "local" one (i.e. incorporating information from a single site only) to a "global" (i.e. capable of storing information deriving from an unlimited number of similar excavations).

With regard to the improvement of the technical aspects of KAIS there is a need for the production of more standard queries for the immediate future. The next stage should be the development of menu-driven integrated applications for the system which will incorporate a number of modules at a time (e.g. ORACLE, RDBI-ORACLE, and ARC/INFO). This will simplify system operations and thus make it more accessible to the archaeologists.

Interfacing with GIMMS in an integrated fashion (i.e. via the GEOLINK module[1]) can be achieved in an effort to provide better thematic maps of the site.

With regard to the digital planning of the site, it is necessary to ensure that all units have been adequately drawn during the excavation (i.e. the drawings should include the definite boundaries of every single unit), including those of type "general". Only then will a visual 3-D excavation presentation and analysis be possible on the computer.

True geographic coordinates should be supplied to define the actual grid location. This will result in the geographic referencing of all features and artifacts falling within the excavated area. A further step forward would be to adopt the use of the Universal Transverse Mercator (UTM) Grid which not only defines areas more accurately but it has also become internationally standardised (units measured in metres) thus solving problems associated with many national coordinate systems[2] (Dills, C.E., 1970, Edwards, R.L., 1969). The use of the UTM grid coordinates will not have a dramatic effect with regard to the recording of a single site. Should, however, a national archaeological database be created the UTM grid will help enormously to the spatial referencing of the excavated sites and their contents in a unified manner.

In order to enhance the efficiency of the system even more, the archaeologists should ensure on their part that all updates in the records and on the plans should be centrally monitored and coordinated and not performed in an ad hoc manner. Moreover, there should be a data recording form developed for each specialist and each data category associated with the excavation.

More codes should be introduced, especially where long rows of text are used to define a record or its attributes. This practice will eliminate the need for a thesaurus to be created in order to impose controls automatically on any possible typing errors. Another advantage offered by the use of codes is the potential for increased data dissemination. This is because cypriot archaeology is a multicultural activity. It involves a number of researchers and institutions from a variety of countries. As a consequence the archaeological data is collected in as many as ten languages. Codes would simplify the situation by first being widely understood and secondly, by offering the possibility of providing a number of look-up tables (defining the codes), in each one of those languages, as a form of dictionary.

Archaeological modelling is another fascinating field which lies open for future research and most certainly KAIS possesses the capabilities of expanding into this field once the requirement arises.

The digital recording of artifacts is also a desirable prospect that could be achieved by the use of a video camera in conjunction with the appropriate software. A scanner could also be used for the graphic cataloguing of the existing photographic record.

The long term aims of both LAP and KAIS involve the development of a survey database to be linked with the existing excavation one. For this, equipment like an EDM (i.e. electronic distance measurer), survey clickboards, magnetometers, resistivity meters and the appropriate computer software for the automatic transfer and display of the resulting data will be required. In the end, a complete Archaeological Information System (AIS) that will incorporate surveys, excavations, special studies, bibliographies, and museum inventories will be produced (see figure 27).

Such a system will be a significant step forward in meeting the requirements for tomorrow's archaeology, but as aptly summarized by the words of Daniel Arroyo-Bishop:

> "All the work and the research that can go into developing a good recording system for today's and tomorrow's archaeology, can only be acceptable from a scientific and social point of view, if it foresees and admits, from the beginning, that one day a better system will emerge. The most important thing in a system is the data that it contains, and it must be possible for it to be, easily and economically, passed to future generations" (Arroyo-Bishop, D., 1989, p. 86).

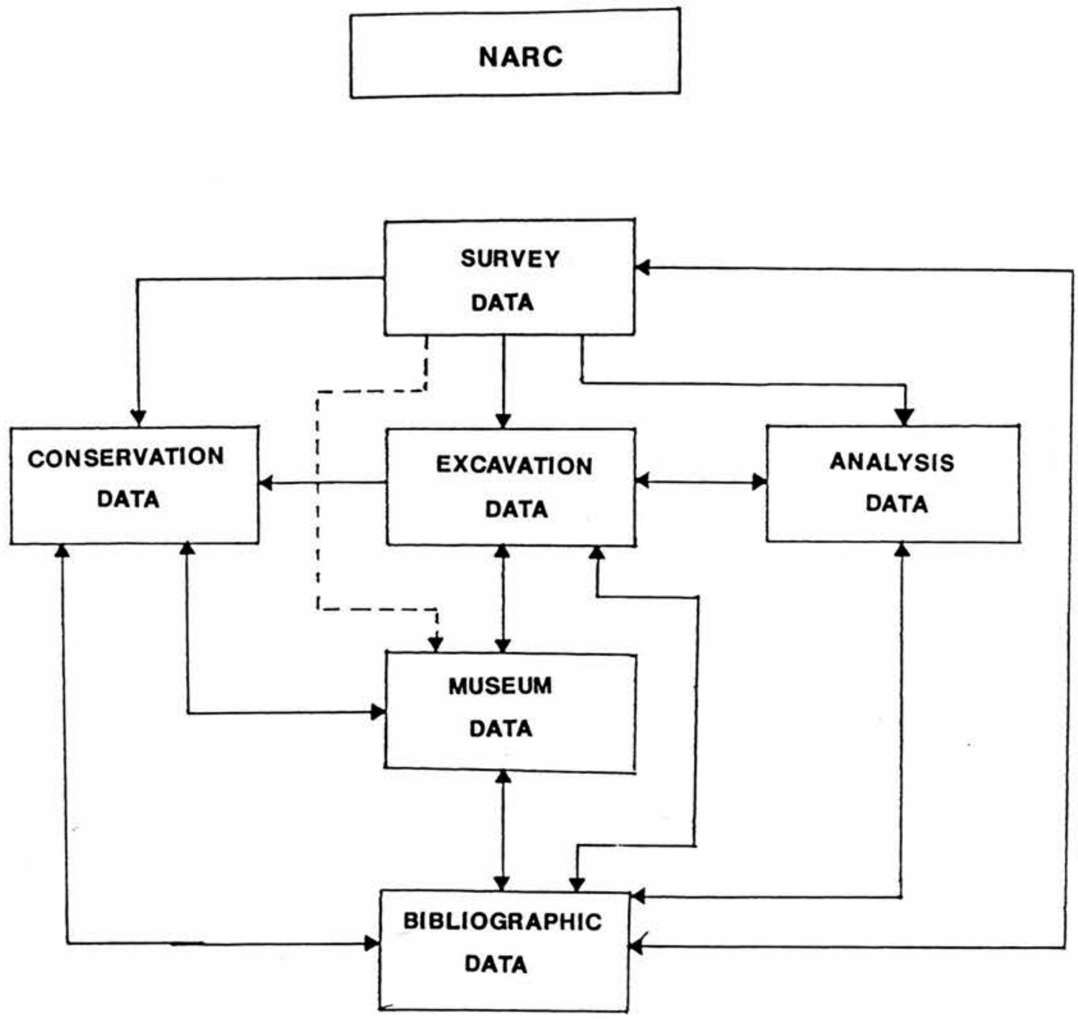


Fig. 27 NARC: General schematic database representation

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[1] See Blakemore, M. (ed.)

[2] For more information on the advantages of the UTM grid see Dills, C.E., 1970 and Edwards, R.L., 1969.

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APPENDIX I-A

-Software used by KAIS

The Choice of Software Packages for KAIS

An attempt follows to describe the major characteristics of the required software, as well as a limited evaluation of the performance of the various packages under the conditions required by the levels of operation at which they are to be applied[1].

1. Anti Virus

This utility is a very important programme to have, especially out in the field where the individual researchers bring in their own diskettes with data to be loaded onto the computer. It can promptly detect and eliminate ever very serious viruses. In view of the variety and effectiveness of viruses now prevalent in large organizations a good anti virus programme is a must for field computer applications such as KAIS.

2. PCTOOLS and NORTON COMMANDER

PCTOOLS is very useful for the rapid maintainance of the hard disk(s), especially when it is close to the limits of its storage capacity. As for NORTON COMMANDER, it provides easy operation of the computer for inexperienced users. It creates a user-friendly environment which is much appreciated.

3. ORACLE and ORACLE PC

This is a fully relational and well established database management system (DBMS), offering facilities such as:

- Generation of database files
- Programming language interfaces
- Data import/export facilities
- Bulk data loader (ODL - Oracle Data Loader)
- Interactive screen design and generation
- Natural query language (SQL*PLUS - Structured Query Language Plus)
- Interactive data querying, either through screens or the query editor
- Generation of macros
- Querying optimization facilities such as column indexing and table clustering
- Wild card querying
- Extensive help facilities
- Data security through data access controls
- Report generator
- Single user or network operations
- Arithmetic and basic statistical functions
- Data exchange with a variety of databases by ASCII format files

Moreover, ORACLE PC is able to run on a wide range of hardware by customizing itself to meet the computer's individual environment characteristics. This is achieved by engaging the user in an interactive conversation during the installation process in which information regarding the hardware characteristics is fed to the programme.

Some problems can be encountered in transferring data from the PC to the mainframe version and vice versa but they can easily be overcome. Some caution should be exercised in ensuring that this inconvenience will not result in any loss of data.

4. SQL*CALC

This is a worksheet attached to the ORACLE and ORACLE PC databases. The statistical facilities that it provides are not quite as sophisticated as those presented by SPSS or MINITAB, and neither does it demonstrate the graphics quality offered by QUATTRO PRO (see discussion in the appropriate sections further on). Nevertheless, it does have the advantage of being able to exchange information interactively with the ORACLE database through a combination command language incorporating both SQL*PLUS and worksheet statements.

5. MINITAB

A basic, easy to learn statistics package with a natural interactive operation language. Suitable for performing a variety of less complex statistical analyses and providing simple graphs. It is available in both mainframe and pc versions. Its major weaknesses are the inability to produce sophisticated graphics and the fact that it is not menu driven.

6. QUATTRO PRO

A simple spreadsheet programme with the ability of executing basic statistical functions but with good quality graphic output facilities (the latest version 3.1 even provides three dimensional graphics). Apart from being menu driven it also accepts data from and provides data to a variety of other programmes either directly or in ASCII format files.

7. SPSS PC

The Statistical Package for the Social Sciences (SPSS) is a well established programme with a market life of over twenty years. It consists of a variety of integrated programmes that provide the following facilities:

- Descriptive statistics

- Simple frequency distributions
- Cross-tabulations
- Simple correlation (i.e. for ordinal and interval data)
- Partial correlation
- Means and variances for stratified sub-populations
- One-way and multi-way analysis of variance
- Multiple regression
- Discriminant analysis
- Scatter diagrams
- Factor analysis
- Canonical correlations
- Guttman scaling
- Data management facilities
- Natural language control
- Programming language
- Both batch and interactive operations

SPSS is considered to be the most complete statistical package available for use on micro computers. Its graphics capability however is very limited and data must therefore be extracted from SPSS in ASCII form and then inserted into QUATTRO PRO for graphical analysis.

8. WORD5, WORD PERFECT 5.1, and 1st WORD PLUS

WORD and WORD PERFECT are considered as possibly the best word processing programmes running on IBM and IBM compatible systems today. An initial comparison between the two shows that the facilities offered by WORD PERFECT are significantly better than those of WORD, especially the variety of languages that it supports as well as the number of printers and letter qualities. WORD, on the other hand, is more user-friendly and more easily handled by the inexperienced user.

WORD PLUS lacks many of the facilities that the previous two packages offer as well as a number of other word processors available at the market. What is in its favour however, is its user-friendly menu driven interface and the fact that it is permanently connected to the laser printer at our installations.

9. GIMMS

GIMMS is a raster and vector based (Zubrow, E.B.W., 1990, p. 188) computer mapping programme (CAM) (Savage, H.S., 1990, p. 23) first established in the 1970's. With the potential of being interfaced with the ORACLE database and statistical packages such as SAS or SPSS (Zubrow, E.B.W., 1990, p. 188) GIMMS can be proved a very useful mapping package (although its capacity will still be limited when compared to

ARC/INFO, for example).

GIMMS demonstrates the following capabilities:

- Generation of maps, graphs, and tabular information of a thematic kind.
- Primitive level drawing
- Coverage error detection
- Map symbol definition
- A wide variety of good quality lettering for annotation
- Key legends
- Ability to run in batch, on-line or interactive modes
- Standard programming or file interfaces
- Interfacing with other systems
- Statistical analysis of input data

The drawbacks found in GIMMS at the basic operation level are:

- Lack of interactive coverage error correction ability
- Low quality shading patterns
- User unfriendly operation language
- In GIS terms, absence of map overlay function

Despite the above hindrances it is still the ideal system in combining geographic features with statistical graphics.

10. RDBI-ORACLE

An interfacing module forming part of the ARC/INFO GIS which allows the exchange of data with the ORACLE RDBMS.

11. ARC/INFO and ARC/INFO PC

ARC/INFO is a vector based GIS developed by the Environmental Studies Research Institute (ESRI). First installed in 1982 (Zubrow, E.B.W., 1990) it has remained successfully in the market for about ten years, a fact that proves its competence in the field. Argued by many as the best GIS released thus far (Peuquet, J.D. and Marble, F.D., 1990, pp 90-99) it consists of two parts. ARC, "a specialized spatial data handling system" (Marble, F.D., 1990, p. 12), which contains the map coverages digitized by the user, and INFO, a relational database management system (RDBMS), containing the attribute tables related to the ARC coverages.

Despite the fact that commercially the INFO database is the one provided with the system, interfaces to a number of other RDBMS are also supported, for example ORACLE or INGRES (Zubrow, E.B.W., 1990, p. 187). These could also be used alongside INFO in providing the additional data required (see RDBI-ORACLE above).

The properties of ARC can be summarized as:

- Interactive map composition
- Multiple map generation
- Windowing and zooming
- Drawing coverage features
- Multiple coverage input
- Coverage error detection
- Primitive level drawing (i.e. draw extra lines or boxes)
- Map symbol definition
- User defined symbol patterns
- Attribute controlled symbolism
- Graphics text composition
- Optimal label placement
- Label overflow handling
- Key legends
- Interactive annotation
- Multiple levels of annotation
- Interactive query of coverage or map library
- Data extraction from map libraries

INFO, as already stated, is a proprietary relational type database and a file handling system. Tables of data in INFO are represented by individual system files. There are two types of INFO data files:

a) Those created within INFO itself such that the data are stored in INFO's internal format and

b) the so called "external" data files. These are normal operating system files whose format and location is made known to INFO so it can read them and select data from them.

ARC/INFO also creates a log file that contains the history of the coverage by recording the type of command issued each time by the user, the date, time, CPU time used, and elapsed time.

It has to be stressed that in both facilities, ARC and INFO, the user can intervene and add, delete or update the information stored at any time.

In terms of compatibility, ARC/INFO PC can also be used. In any other case, data should be stored in ASCII form on a floppy or hard disk of any micro computer and then transferred to the VAX where ARC/INFO is presently installed. A reference system (in the ARC system) of X,Y co-ordinates should be used however, in order to keep track of feature locations.

12. TIN (Triangular Irregular Network)

A digital terrain modelling (DTM) optional module attached to the ARC/INFO (mainframe only) package. Being fully integrated it takes advantage of an extensive variety of the existing ARC/INFO utilities as well as sharing some basic commands.

Triangulated irregular network, TIN, offers facilities such as:

- Area 3-D visualization
- Rotation and viewing angle selection
- Filtering (to remove potential "noise" from model)
- Surface analysis
- Draping (a facility by which previously created coverages are "draped" over the DTM).
- Cross section analyses

Appendix I-A - Endnotes

[1] All comments offered on the programmes regarding their characteristics were obtained from the relevant manuals. For ARC/INFO however, use was also made of the 1988 tutorial notes distributed at the Dept. of Geography by R.G. Healey and B.M. Gittings.