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A digital model of archaeological excavations as the starting point of a database of primary information in Egyptology: method—procedure—experience

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7.1 Introduction

The idea of attempting to build up an as comprehensive as possible database of both archaeological and egyptological information from archaeological excavations was born almost four years ago; however, at that time we had not any means to carry it through. Nevertheless, we made our first steps then: we tested a basic system of describing individual artifacts and storing the resulting information into computer memory. In this work, we could draw from the experience gained with so-called 'analy-cards'.[1]

At that time what we were lacking most was a persistently accessible and available computer. For this reason, our work was rather limited to projects and theoretical

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[1] An A5 DIN size card, double-punched along its edges, which has been used by the Czechoslovak Institute of Egyptology of Charles University for describing of findings since the mid-seventies. The creation of a suitable punching code in 1983 and 1984 brought first experience to one of the authors.

considerations which, however, were not interrupted even in the years to come.

One of the results was the recognition of the necessity of solving the topological component storage on memory media. In this respect, we soon became aware of the difficulties associated with describing the topological component structure for the purpose of data storage. The importance of this component of all information as the most important connecting link of individual artifacts and objects, or between individual artifacts, is generally known. It should be said that there are not many purely geometric relationships involved, but rather spatial relationships representing chronological and functional ones (Hodder & Orton 1976, p. 241). Consequently, associations of archaeological artifacts and defined parts of objects (rooms, layers and deposits) should be preferred to purely geodetic data.

Obviously, it was necessary to find a way of storing as complete topological information as possible into the computer memory. Hence, our efforts during first stages were focused mainly on the problem of digital modelling of archaeological objects and of their intrinsic structure which would become a natural support for sorting and defining internal relationships found out by archaeological excavations. As creating models of various kinds for various purposes and based on different data is very common in archaeology, it soon became clear that the digital model could be used as a base for other needs and kinds of model creating, as well as for formulating and testing hypotheses, verification of archaeological evidence etc.

When—owing to the support of the Czechoslovak Television Praha,[2] which needed some unconventional shots for its programme on Czechoslovak egyptologists, and the understanding on the part of the Design Institute of Transportation and Civil Engineering Structures (hereinafter acronymized as PÚIS) management—there emerged an opportunity for our concepts to be materialized, we started preparing a digital model of the Mortuary Temple of Raneferef[3] at the Unfinished Pyramid at Abusir. The model was based on archaeological evidence of the 1982 and 1984 seasons.[4] At present, the model shows the situation based on the results obtained at till the end of 1984.

7.2 Description of the method employed to create the digital model

The procedures employed to create the digital model of the archaeological excavations site are based on original methods of digital terrain modelling developed by PÚIS Praha in the late seventies and early eighties (Eisler & Falkenauer 1979, Eisler 1981, Eisler & Skladal 1981, Eisler 1982). As early as at that time, there were first attempts to use them in archaeology (Eisler *et al.* 1981, Eisler & Smetanka 1981), which we have been able to draw from later.

The term 'digital model' denotes a numerically presented grid which represents the terrain relief, architecture, remnants of various archaeological objects etc. and which provides input data for subsequent computerized operations, eg computerized graphic plotting.

[2]On this occasion, we would like to express our gratitude especially to Doc. Dr. J Bonek

[3]A 5th dynasty king

[4]The model was limited to these two seasons because their documentation substantially improved the results of the 1981 survey, while the 1985 documentation was not then available in Prague and the 1987 season was not yet completed

Generally, the construction of the grid is based on different approaches in various digital modelling concepts. However, these can basically be divided into two groups:

1. models based on a regular square grid (or a regular triangular one resulting from placing diagonals into the grid squares). Apices of the grid are derived from measurements of detailed altimetric points using various interpolation methods.

2. models based on an irregular triangular grid constructed immediately from the detailed altimetric points using various criteria.

In our case, *i.e.* in the case of the digital model of an archaeological excavations site, as well as in other digital terrain models, developed by PÚIS Praha, the irregular triangular grid approach was chosen. The criterion employed for the automatic creating of the grid based on detailed points is the minimalization of leg lengths of all the triangles constructed in this way.

7.2.1 Inputs

Inputs into the digital model are detailed points described by triples of coordinates, Xi, Yi, Hi. Consequently, the digital model can be used to represent any space-related phenomenon, *i.e.* a phenomenon whose position in different points can be expressed by X and Y coordinates a whose value can be described by the coordinate H. The only limiting condition is that only one Hi value can be associated with each pair of Xi, Yi coordinates (if illustrating this requirement on a terrain example, the relief should have no 'overhanging').

The coordinate system can be selected: either a national or a local coordinate system can be employed. It is also possible to transform the model from one coordinate system to another one and vice versa. The only requirement in this respect is that the entire object or area to be modelled must lie within a single coordinate quadrant and all its X and Y coordinates must be positive.

Coordinates from geodetic measurements can be obtained either from surveyor's notebook, or from surveying instruments recording the data immediately onto a magnetic memory unit, in both cases in a digital form. It is also possible to read coordinates from a map, a plan or a photogrammetric photograph. The same applies to coordinates obtained from design calculations, there where redevelopments of the original landscape or building patterns are involved etc.

Places where the configuration of an object or terrain displays an abrupt change (edges of buildings, embankments, roads, unearthed objects etc.), valley lines and crest lines, are described using so-called *'singular points'* or so-called *'obligatory connecting lines'*. These points, or lines connecting them, must be specified before the digital model construction can start. This means that these connecting lines are automatically legs of the grid to be constructed and must not be crossed by any of the automatically created legs drawn afterwards. The software employed for constructing digital models automatically guarantees that this requirement is met. The remaining points, *i.e.* those where the terrain or building configuration is continuous, are denoted as *'regular points'*.

In addition, it is possible to specify and define in advance the so-called *'islands'*, *i.e.* areas where, for some reason, the grid construction is undesirable.[5] The grid is also

[5]The 'islands' are used, for instance, in altimetric maps to represent ground plan areas of buildings, water areas etc.

not constructed there where the terrain is described by a less dense point field than the point density criterion 'Δ', specified by the user for a given triangular grid. This feature guarantees that the digital model is constructed only there where it truly represents the shape of an object or terrain relief with a sufficient precision.

Last but not least, it is possible to define different objects in terrain[6] such as existing walls, buildings, earth fills, as well as objects already nonexistent, currently designed, or those whose position or appearance is being reconstructed. The shape of such objects is described by a set of points which determines the ground plan position of their corners, roof gables and similar singular points and obligatory connecting lines, and altitudes of individual parts of the objects (most frequently by projecting onto a preset projection plane).

7.2.2 Outputs

Using the file of input data prepared in the way outlined above, a computer is then capable of:

- plotting (on a given scale) all points of a file, including their identification numbers and, optionally, altitudes (*'MAPOS'* programme),
- the same as above, but including all obligatory connecting lines,
- plotting the topographic situation of an archaeological object or an area of interest (location, site),
- generating a so-called morphometric file which contains both point numbers and coordinates, and data for connecting all these points by 'obligatory connecting lines'. This file represents the base for constructing a triangular grid,
- constructing a digital model (irregular triangular grid) conforming to the criteria specified above, and storing the data describing the model onto a memory unit from which the information can be retrieved for creating and plotting various drawings (and generating outputs).

If processing the data further on a computer, it is possible to obtain the following outputs:

- to generate and automatically plot on a given scale altimetric isolines (contour lines) of a given object or terrain ('IZOL' programme, Tondl 1976),
- to generate and automatically plot on a given scale cross-sectional views of an object or terrain; either individual cross-sectional views defined by a pair of points defining the view plane, or a system of cross- sectional views perpendicular to any of the X or Y coordinate axes, or to any line specified (the step between the cross-sections on their axis can be selected) are available (*'REZ'* and *'KREZ'* programmes),
- to generate and plot views of an object, site or area (or any part of them), which are constructed using the cross-sectional view system described above. The

[6]Either situated on the terrain, or sunk

standpoint and projection method to be employed (axonometry, isometry, linear perspective etc.) can be selected. The so-called 'hidden' lines can be automatically suppressed in the resulting plotting (*'AXONH'*, *'PERESH'* programmes). An identical object can thus be plotted in a bird's eye view from a distance, or as if viewed by a man passing around or through (Pejsa *et al.* 1985a, Pejsa *et al.* 1985b), or in an axonometric view from above. It is also possible to model views from an otherwise inaccessible standpoint, or from a place where an important part of the object, if photographed, is hidden behind an unremovable obstacle which can simply be 'deleted' in the input data.

It is worth nothing that the input data, once specified, can be modified, *i.e.* it is possible, for example:

- to transform the data into different coordinate systems as necessary[7]
- to eliminate certain objects or their parts in a model (eg 'tear down' later annexes etc),
- to add other objects into a model, or to change their height (or shape, if necessary,) etc.[8]

A simple modification of data thus results in creating new derived digital models (triangular grids) constructed by the method described above, and new modified outputs, including all plotting required, are generated.

7.3 Digital model preparation

The complete procedure of constructing a digital model can be demonstrated using the example of the Mortuary Temple of Raneferef digital model. It can be divided into the following stages:

- data acquisition and preparation
- data storage
- digital model generation
- generation of graphic outputs

A special chapter is represented by the verification of the generating procedure and by examination of a creation and testing hypothesis concerned with the architectural development of the temple and its reconstruction, as well as reconstruction of certain stages of the destructive activities (as an example of the solving of an archaeological situation). Another chapter makes necessary storing of the results in an archive.

[7]Eg from a local into a national or general geodetic system. The transformation can also be employed to eliminate statistical errors of measurements etc

[8]And thus, for example, to model the shape of an object during different construction and development stages, to reconstruct its original appearance, and to solve similar tasks

7.3.1 Data acquisition and preparation

The essential purpose of this stage is to establish a link-up to field works.[9] In our case, this meant a link to the works completed during the 14th and 15th Czechoslovak Archaeological Expeditions to Egypt.[10] Owing to the fact that the archaeological field documentation (especially archaeological plans) was obtained by an orthogonal method with a combined situation recording,[11] it was necessary to digitize these background documents prepared in Abusir.

In this stage, the basic problem is always represented by having to find a suitable data organization system. The model of the Mortuary Temple of Raneferef presently contains information on several thousands of points belonging to different phases of the temple construction and, later, destruction, and on subsequent uses of this area. Obviously, no graphic output can present them all at a time, so that it is necessary to keep them separated into several data files according to their character.

The division into these data files should take into account the internal structure of the object to be modelled. This very requirement, calling for the overall archaeological situation and object structure to be accounted for when formulating the contents of the data files, is essential for facilitating subsequent operations with the model. Naturally, it is necessary to take into account the maximum extent of these files, which is given by the fact that the point number should have only up to four digits.

In this respect, it is worth noting that is it not possible to use all numbers throughout their sequence for several reasons. On the other hand, it is not advisable to establish too small files, with each file representing a small structural element (eg an additional bricking-in of a door etc). An immense number of files would result, which would make the orientation within the model very difficult. Consequently, establishing files representing categories of phenomena (eg all additionally bricked-in doors etc) seems to be the best approach. At the same time, it is not necessary for all individual phenomena within a single category to have taken place at the same time—their individual incorporation into the model for outputs, viewed from the standpoint described above and with respect to other aspects will be explained later.

Within a given file, numbers are allotted to points sequentially: to the beginning of the fact to be described is given a number whose last digit is always '1' (eg '51', '231', '1381', etc) This simple approach later allows for a better orientation within the data files and facilitates the detection of errors, modification of files etc. Its importance also consists in the fact that there must be worked out a file describing obligatory connecting lines to every file containing data obtained by digitizing the primary documentation. The file is thus represented by a number of records, each corresponding to a particular individual phenomenon—and its incorporation or omitting during the processing phase results in the phenomenon being or not being incorporated into outputs.

After all, the detail and accuracy of a given fact (reality) being represented by a

[9] If the data is recorded immediately in the field using suitable memory medium (eg connected to a tachymeter), maximum attention must be paid to the data organisation, which is—especially there where complex situations and structures are involved—very difficult and, in our opinion, the archaeologist is in this case faced with disproportionally excessive time requirements

[10] Both expeditions were headed and the archaeological excavations directed by Dr M Verner, CSc

[11] Digital coordinates are not written down into a surveyor's notebook, but directly plotted, the situation being drawn directly in the field. This method allows for visually checking the results on the spot (for details see Simana 1971, p. 47–48).

digital model depend mainly on the quantity of points digitized (provided by the primary field documentation). Every important point in these documents must thus be given an identification number. The term 'important' denotes every point delineating a certain fact (phenomenon), or every point where the line passing through it breaks horizontally or vertically.

In compliance with the principles outlined above, the facts contained in the archaeological documentation of the Mortuary Temple of Raneferef excavations have been divided into 23 classes, with corresponding data files labelled 'A' to 'L', and 'P' to 'Z'. The 'M' file has been reserved for geophysical prospection data, the 'O' file has resulted from a merger of the 'C', 'D' and 'E' files.

Our practical experience suggests that the best procedure to employ is that which involves numbering points, setting up obligatory connecting lines and establishing an aid which facilitates and speeds up the process of associating altimetric coordinates during digitization taking place at the same time. In practice, an A4 page is divided into columns. The first, broader one has been used for putting down the specification record of a bottom singular edge in a ground plan view), three next (narrower) ones were used for altimetric data obtained from the primary documentation (altimetric measurements), arranged from the highest to the lowest values (ie from the wall crest to its foot.[12] The last (broad) column contains the specification for the derivation of altimetric singular edges.

While the specification of basic obligatory connecting lines may follow contours of larger elements, that for the derivation of altimetric singular edges must be approached carefully and taking into account the overall situation. In fact two sets of specifications must be prepared for these edges, which, on the other hand, greatly facilitates and speeds up the process of creating the model, and minimizes difficult and unpleasant interventions into the process in its later stages. The first of the specifications is intended for the 'OBRUV' programme which was written specifically for archaeological operations and whose purpose is an automatic take-over of altimetric data there where top edges of structural elements are very uneven, a situation fairly common in our case. The other specification is intended for structural elements with quite horizontal surfaces, especially staircases, straight terminated walls etc., and is processed by the 'OBRUB' programme.

7.3.2 Data storage

Upon completing the preparatory stage described above, it is possible to start digitizing the data and to store the digitized data onto the computer memory media. The most frequent form of this process is that using a digitizer which, apart from its high accuracy, also guarantees a high digitization rate and a minimum amount of errors. Larger plans have usually to be divided into smaller sections digitized separately for this purpose. The digitization need not take place at a time: the digitized data can, at any time, be supplemented by those from additional documents (eg excavations plans made

[12] Where two walls meet (each having a different height), and especially where staircase bends are involved, several altimetric values are 'stacked up'. Complying with requirements of the digital modelling then requires careful work when preparing the specification for the derivation of an altimetric point. This problem will be discussed in detail later.

during other seasons etc.)[13] The combination of the separately digitized files into individual files according to importance is, as described earlier, accomplished after a transformation into a unified (local or general) geodetic system, by merging. The logical number of a file was then the ordinal number of its letter designation in the English alphabet.

The files digitized directly from primary sources on the digitizer worktable were labelled 'S' files and the designation also included the number of the digitized section of the primary documentation, and a phenomenon class letter (eg S3B).[14] At the same time, transformation files including digitized points with calculated geodetic coordinates were labelled 'T' and the number of the digitized section of the primary documentation. After having been transformed, the files were labelled 'G' (the designation of the class was not changed) and concatenated to the first file.[15] This system allowed for a very fast orientation within the multitude of files and maintained their interrelationships.[16]

During the digitization process, values of the highest altitudes were also stored in addition to the automatically scanned and stored topographic coordinates. The necessary information on basic altitudes was later stored in files labelled 'GZ' in their place.[17]

The storage of specifications into the computer memory is one of the operations which cannot be automated and, consequently, is the largest potential source of errors. For this reason, maximum attention must be paid to the preparation of the documentation as early as during the preceding stage, which is really worth it. Three types of specifications were prepared: for basic altitudes (lower edges of the walls), for top singular edges processed by the 'OBRUV' programme, and for those edges processed by the 'OBRUB' programme. Instruction specifications for the derivation[18] must be prepared for the second and third types.

The digitization of the data contained in the documentation of the archaeological excavations was accomplished using a Czechoslovak-made DGZ 1208 digitizer the accuracy of which is 0.05 mm.

The digitizer was linked up to an ADT 4500.1 minicomputer. The digitization completed, files of 'table' coordinates were gradually transformed into geodetic coordinates

[13]Thus, it is possible to supplement the model and its data files by fresh information obtained in the field, even after longer periods of time. It is expected that the digital model of the Mortuary Temple of Raneferef will also be supplemented by the information obtained during the 1985 and 1987 seasons, especially by geodetic data from the measurements carried out by Doc.Ing. O.Vosika, CSc and Doc.Ing M. Svec, CSc of the Faculty of Civil Engineering of the Czech Technical University

[14]This file was then given a logical number /SS 32, after its connection to the appropriate file of geodetic coordinates the number /SS 2.

[15]Owing to the fact that these files have incorporated all table files of a given phenomenon class, it was enough to mark them with number '1' (eg G1B = /SS 2 etc). Other numbers remained reserved for files with interpolated points or points supplemented by algorithmization, for generating hypotheses and other purposes

[16]We would like to thank RNDr. M. Grösslova for her help in processing a logic system of the files marking

[17]It was accomplished quite easily, because most of these data are based on floor levels which are more even. Consequently, there is less variability involved, this fact allowing for employing mass instructions for their modification.

[18]The specification designation was based on the designation of point files *i.e.* 'P' (basic specifications), 'PO' (derived specifications), eg P1H, P01HS (for the 'OBRUB' programme) and P01HV (for the 'OBRUV' programme). Instruction specifications were labelled 'A' (using the above example, the corresponding designations are A1HS and A1HV).

in a selected local network, the beginning of which was set 1,000m to the west and 1,000m to the north of the excavated temple.[19]

7.3.3 Digital model generation

The digital model generation takes place in three stages. First, the preliminary stage consists in the derivation of points of top singular edges by the 'OBRUV' and 'OBRUB' programmes mentioned above. The first one, at the same time, provides for irregular altitudes to be automatically introduced into the digital model.[20] This substantially reduces the volume of work in the two subsequent stages.

As extensive models are often characterised by a fairly irregular distribution of points over the area and there are a high number of points involved, it is necessary to solve them in several parts from which the final output is generated. To incorporate all connecting lines (even those whose end points do not fall within the grid these lines pass through), the 'INTER' programme have been employed, which automatically interpolates the necessary supplementary points. The 'UPRAV' programme converts the relative altimetric coordinates into the absolute altitudes.

The digital model proper is generated in two stages. The 'PGRIA' programme first generates point field files and files containing pairs of points representing specified singular points, ie specified obligatory connecting lines. Thus, the priority of these connecting lines is automatically provided for.

The next stage is the establishing of a complete irregular triangular grid by the 'KIGRI' programme.[21] An important criterion is the 'Δ' value which represents the longest arm of the triangle. As described earlier, the triangular grid is not constructed there where the point field is not dense enough (distances between its points are in excess of the 'Δ' value). On the other hand, if a high value of 'Δ' were selected, the calculation would be slowed down significantly[22] or even stopped because of the computer memory being overfilled.

The model construction in these stages is mostly automatic and the human role is increasingly limited to checking the computer operation and results. When constructing the digital model of the Mortuary Temple of Raneferef, output morphometric files were first linked up into phenomenon class units (the resulting files were labelled 'MPA' ...). Owing to the capacity of the computer built-in storage, the complete digital model was divided into nine parts (individual grids with overlaps).[23] The point field files were labelled 'BE' (and the grid number): similarly, the point pair files were labelled 'DE' ('PGRIA' programme) and 'IE' ('KIGRI' programme).

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[19]Transformation results (protocols of the 'TRANS' programme) show that the intrinsic accuracy of the model obtained (on a 1:1 scale) was better than 1.6 cm, *i.e.* better than 0.32mm on a 1:50 scale (which was the primary documentation scale). This fact suggest that the accuracy and, hence, the approach selected were quite adequate.

[20]From the 'G' type file, where the top altitudes were stored in the course of the digitization

[21]The grid can also be simultaneously plotted, which is a very convenient form of visual checking of data, especially of the correct derivation, where it is not uncommon to find many mistakes the detection of which in the subsequent stages would represent an unpleasant delay and interrupted work.

[22]The calculation takes into account and checks all points within a given range, but their number must not exceed 250

[23]The maximum number of points in one part of the model should not exceed approximately 1,500.

7.3.4 Generation and plotting of graphic outputs

The current software developed by PÚIS Praha allows for generating various views of the reality being modelled. Views at different angles and from various standpoints can be selected. The human eye view corresponds to linear perspective; however, its inherent disadvantage is the accumulation of lines in the background of the view. Clear and illustrative views are produced by axonometry which has also been chosen for plotting views of the Mortuary Temple of Raneferef at Abusir.

Archaeological applications can advantageously make use of the plastic impression inherent to views based on a system of cross-sections viewed outside their axis. For this reason, all parts of the model are first 'sliced' into a unified system of cross-sections by the 'REZ' or 'KREZ' programmes, and the results used in the following step for axonometric or perspective calculations (or another form of projection), with hidden lines either suppressed or not (however, the suppression of hidden lines is always desirable for us).

This work has resulted in graphic outputs clearly illustrating the advantages and capabilities of the selected method. They can be very well compared with photographs taken during excavation works. The comparison regarding to the different technique of representing in a picture indicates the overall accuracy and low degree of generalization of the model, which make it suitable as a base for the topological component of the database as well as for many other purposes.

7.3.5 Verification of the procedure of generating and testing of hypothesis

During the construction of the digital model, the issue of its application outside the database emerged. Above all, we were interested in its potential applications in attempts of reconstructing the temple interior, in formulating and testing hypothesis on the temple development in certain stages of its existence.

These problems too have been approached using the digital model of the Mortuary Temple of Raneferef. We have experimented with removing some younger parts of the structure and, on the other hand, with interpolations or algorithmized supplements of some (probably covered or damaged) structural parts to achieve a certain hypothetical arrangement. We have employed the 'open roof view' method.[24] The resulting views can then be assessed from the viewpoint of architectural history knowledge and experience, additional information etc., and plot their details according to requirements.

So far, these steps have just indicated some other potential applications of the method: for instance, the same procedure can be used to reconstruct some destructive activities in the temple area, or to assess different archaeological situations and in many other cases. The important fact is that these steps are based on exact and accurate data checked throughout the course of the archaeological work, which can be verified at any time. Most of all, our experiments have learned us how to work with the digital model of the archaeological excavations.

[24] In mathematical terms, the operation was fairly simple, consisting in projecting onto a given projection plane

7.3.6 Storage of the model in archive

An integral part of the model construction is the storage of the files and results in an archive. It is indispensable not only for a further reconstruction of the procedure used, but mainly because that it is impossible to have all the data stored in the computer memory unit and thus block it for other work. A suitably stored model in an archive is always, even after a long period of time accessible.

The methods used for storage of the model have been worked out concurrently with the model construction. Their part is the files designation system described above, which allows for remembering it fairly easily (although a great number of files is involved) and which is clear and simple. Naturally, one cannot rely on one's memory; everything is stored in appropriate manuals.

Key nodes of the work have been documented by printed listings; apart from continuously recorded safety copies (so-called 'back-ups'), a magnetic tape with all data needed for subsequent operations has been established.

7.4 Hardware and software used

The core of the hardware employed to construct the model was an ADT 4500.1 CPU whose built-in storage capacity is 128 Kwords (16 bit). Two EC 5061 disk units, 29 Mbyte each[25] two SM 5403 disk unit, 5 Mbyte each[26] represented external storage capacities. The primary documentation was digitized on a DGZ 1208 digitizer (as mentioned above), graphic outputs were produced by a Digigraf DGF 1208 plotter. A Videoton line printer gave listings.[27]

The work has been carried out under the operating system DOS 5 (but also DOS 4 can be used). The software employed, 'LISPU—the group of exercises for the altitude processing ' is the original product of the development and possession of PÚIS Praha.[28]

7.5 Use of the model in the archaeological practice

The digital model of archaeological excavations can be used to solve different tasks and just throughout the entire cycle of research; in the field work as well as in processing and interpretation of findings and observations. The first use of the model can be considered as early as during the preliminary geodetic survey. In this stage, it is possible to obtain a terrain model before commencing the survey (if necessary, even with surface traces of the object, especially if a convenient superelevation is used).

The methods outlined above can also be employed to advantage to process results of geophysical prospecting. Tests in practice and comparisons with results of excavations itself show that graphic outputs of the digital model display a high degree of detail and

[25] For data storage. Their storage in an archive was made on a 9 track, 800 bpi, magnetic tape in standard ASCII (EBCDIC is also possible).

[26] For operating system and programmes

[27] For recording extensive digital models of archaeological excavation sites, experience shows that the built-in storage capacity should be at least 64 Kbyte and the disk storage capacity in the order of several Mbyte. In addition, a medium- or large-format digitizer and an accurate plotter capable of producing graphic outputs up to A1 DIN size are necessary

[28] This is where detailed information, user and programming documentation can be obtained. In case of interest, PÚIS Praha will also furnish further necessary information. All information is available at the address: Ing. Jiří Pejsa, PÚIS Praha, Lidových milicí 69, 112 70 Praha 1—Nove Mesto, Czechoslovakia

are capable of the objects being surveyed.[29] The example of data obtained during the geophysical survey of the area of the Mortuary Temple of Raneferef is convincing enough (see Hasek *et al.* 1982, Hasek & Preuss 1987). Such a model based on geophysical data can be, owing to its clarity and illustrative capability, easily employed for planning and managing the field work.[30] Naturally, data from other kinds of prospecting can be processed as well, such as phosphate analyses (Krajic *et al.* 1985) etc.

Obviously, results of the archaeological survey proper represent the base of the model. The task of the model, as far as its processing is concerned, consists in assisting in gaining fast access to necessary information, in interpreting different terrain situations and verifying whether the particular interpretation is correct, in providing all conceivable help in examining the character and development of the object under survey. The model can meet these requirements, if the input data and information are accurate enough and if the model capabilities and properties are properly used, *i.e.* especially if detail levels and the generalization of the modelled objects (or its surroundings, a group of objects, an excavation site) are adequately selected. The model variability, clarity and complete accuracy are principal advantages in this stage of work.

The Mortuary temple of Raneferef was not chosen to be the first modelled object just by a chance. As early as during the work with 'analy-cards' dealing with findings in the Mortuary Temple of Queen Chentkawes[31] at Abusir, there were indications that this kind of medium was suitable for preserving information only up to a certain number of findings.[32] The rapidly increasing number of findings[33] necessitates looking for new, readier media for the storage, sorting and processing of information on these findings. Our archaeological investigation too faced this problem in the early eighties. The large and mostly well preserved Mortuary Temple of Raneferef has provided much information of various kinds. Its complex design and structure developing in a number of stages, the fairly long time for which the temple was used, many later interventions and natural impacts alternatively effecting its ruins—all these factors have combined to represent conditions for testing the digital model of archaeological excavations under the most demanding circumstances.

7.6 Conclusions

Although a truly comprehensive evaluation of the contributions and importance of the digital model of archaeological excavations we have constructed, methods employed to construct it, different possibilities and trends of its applications etc. will undoubtedly require a longer time, it is possible to say even now that the method and the model itself have certain advantages differentiating them from experiments carried out in this field so far. These advantages consist mainly in:

[29] We would like to thank RNDr. V.Hasek, CSc, Geofyzika Brno, for providing the necessary data

[30] At present, a publication on the assessment of other methods processing geophysical data and combined with the digital model is being prepared

[31] Mother of two (?) kings, 5th dynasty

[32] Actually, the number is fairly low—in our experience it is efficient up to 250 cards

[33] Mainly due to the application of modern historical approaches to archeological sources and their comprehensive processing, that the present explosion of archaeological artifact and information on them is taking place

- the high degree of data flow automation, which might be even increased (providing there is a good organisation of field work),
- the flexibility and modifiability of the model and its individual parts,
- the easy suppression of errors and the high level of software control,
- the low degree of generalization which allows for an acceptably accurate presentation of details,
- the capability of constructing very extensive models at a considerable degree of details,
- the capability of constructing models based not only on geodetic and archaeological data, but also on data from geophysical prospection and other sources, using the same programmes,
- the capability of making use of different graphic outputs based on a single set of data and a single model,
- the suitability of the model as a base of a topological component of a database of archaeological excavation information

Based on the evaluation of the advantages outlined above, we trust that the digital modelling methods of archeological excavations elaborated through our mutual cooperation will find a broad range of applications both in archaeology and egyptology. Archaeological institutes and departments in Czechoslovakia have already shown interest in them.

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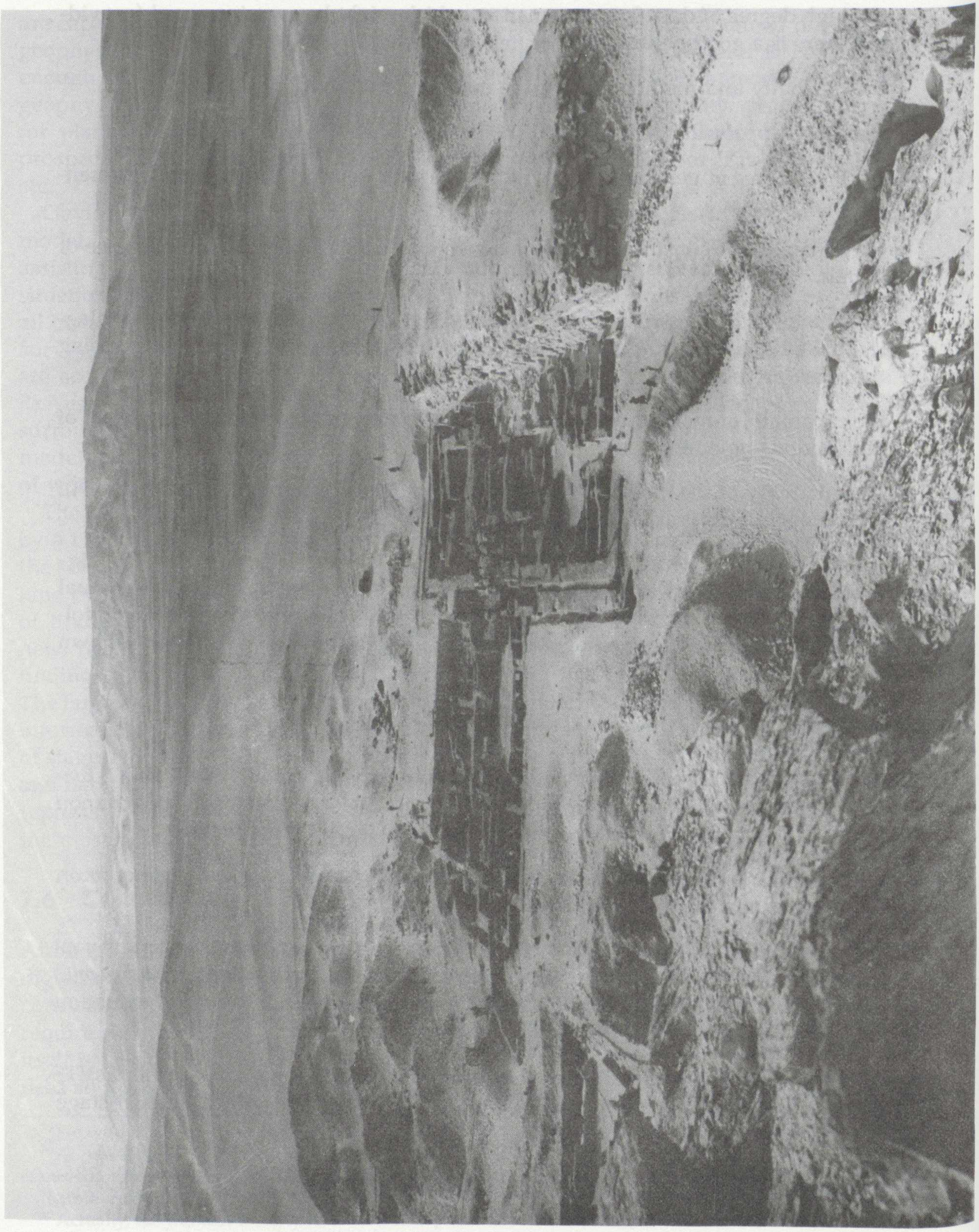

Figure 7.1: The Mortuary Temple of Raneferef in front of the Unfinished Pyramid at Abusir

Figure 7.2: The Mortuary Temple of Raneferef—an axonometric view (excavations stage end 1984)

Figure 7.3: The Mortuary Temple of Raneferef—a reconstruction of an early stage of construction (an axonometric view)

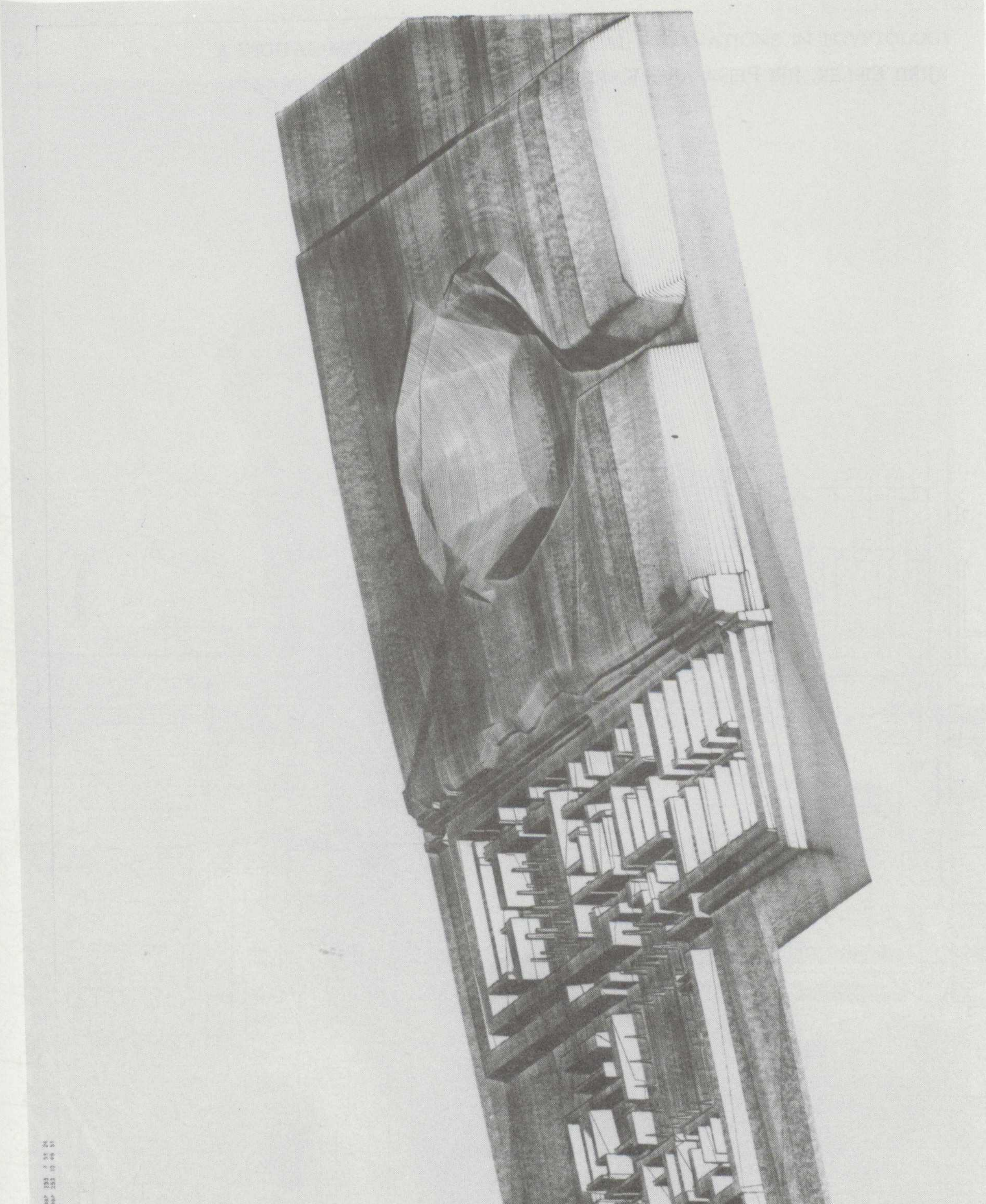

Figure 7.4: The Mortuary Temple of Raneferef—a reconstruction of a later stage of construction (an axonometric view)

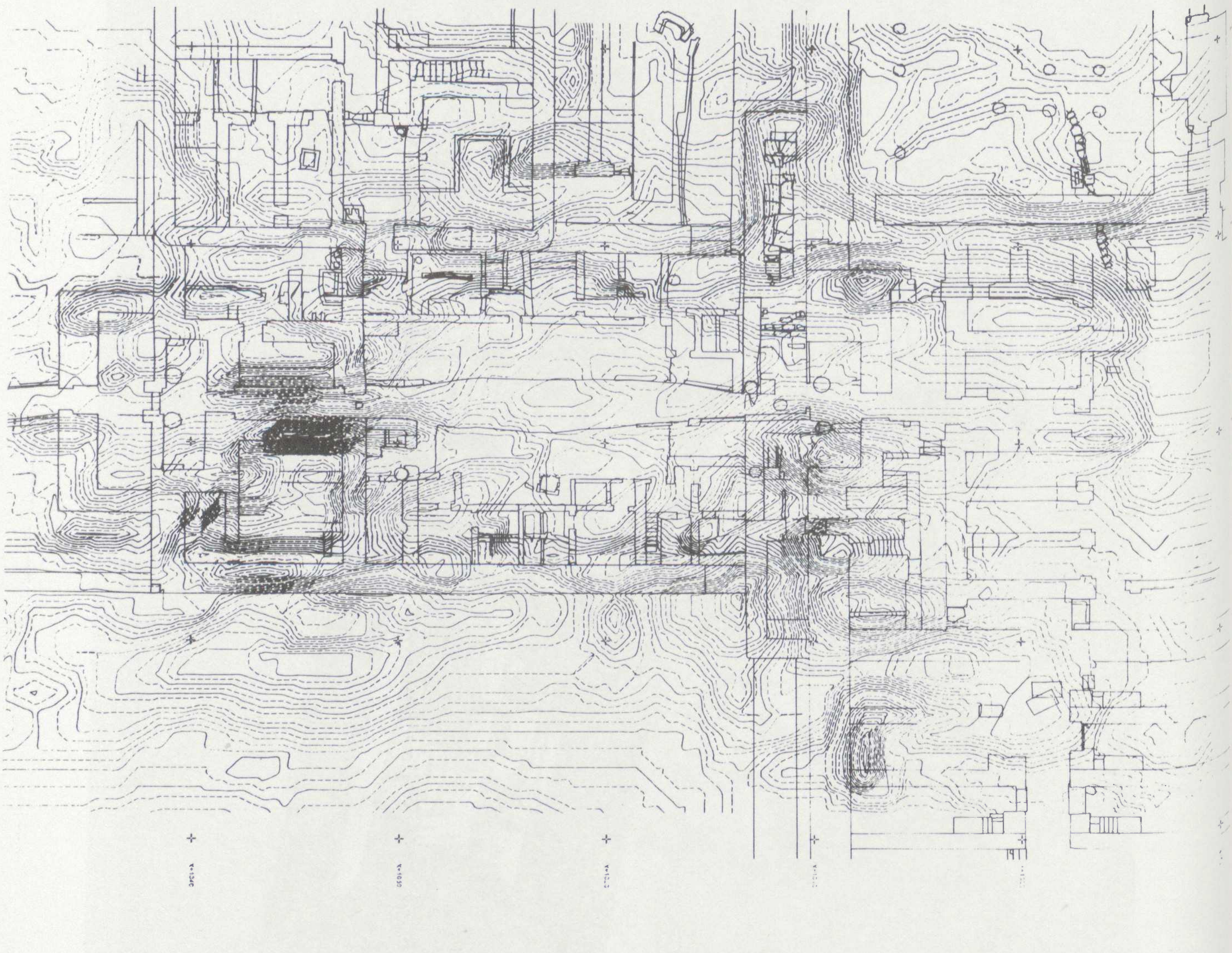

Figure 7.5: The Mortuary Temple of Raneferef—isolines based on the data of the geophysical survey as compared with a sketch plan of the temple

Figure 7.6: The Mortuary Temple of Raneferef—an axonometric view processed from the data of the geophysical survey

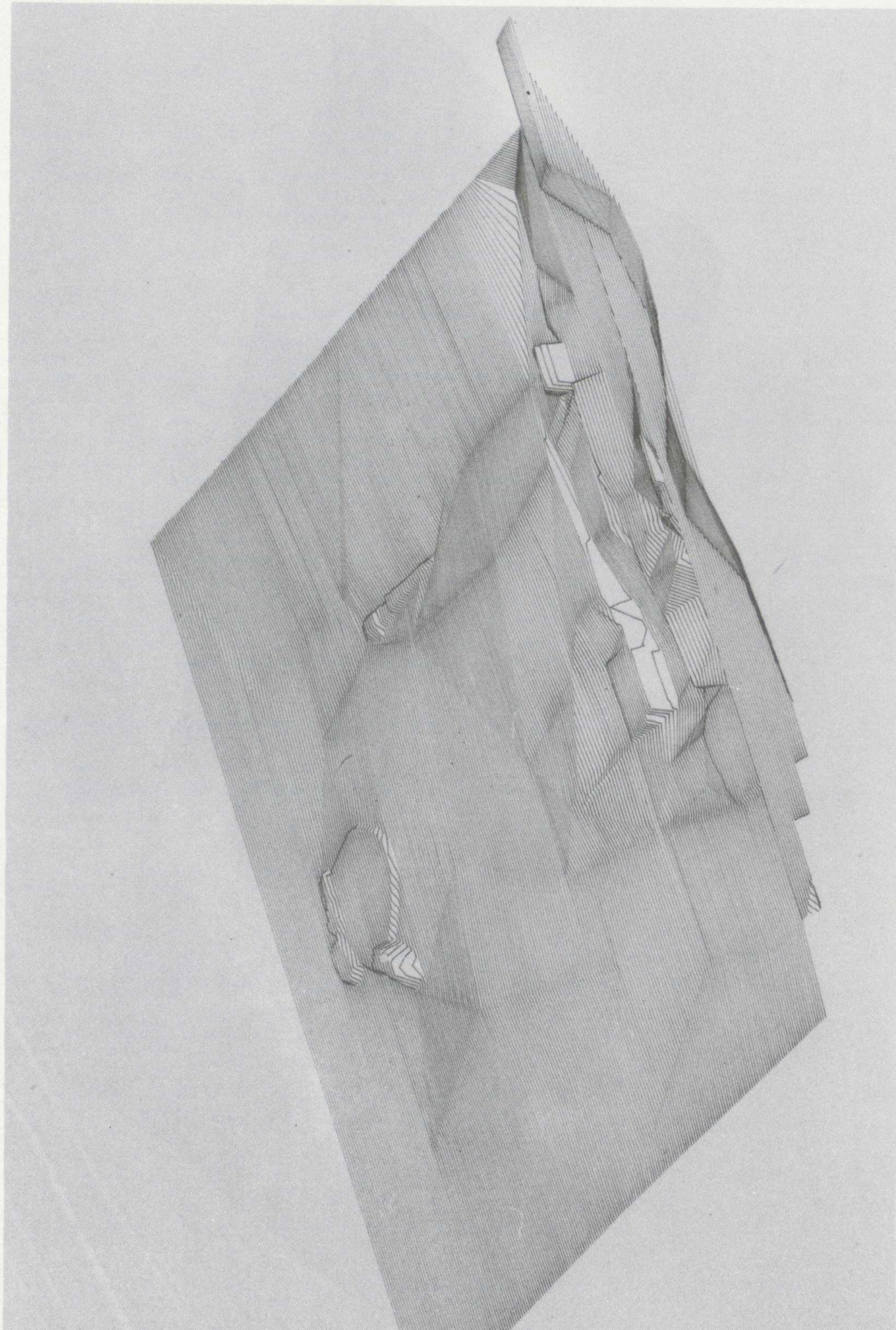

Figure 7.7: A destructive activity in the hearth of the temple: the plateaus for destruction of stone and a way for lifting of the quarried stone (an axonometric view)

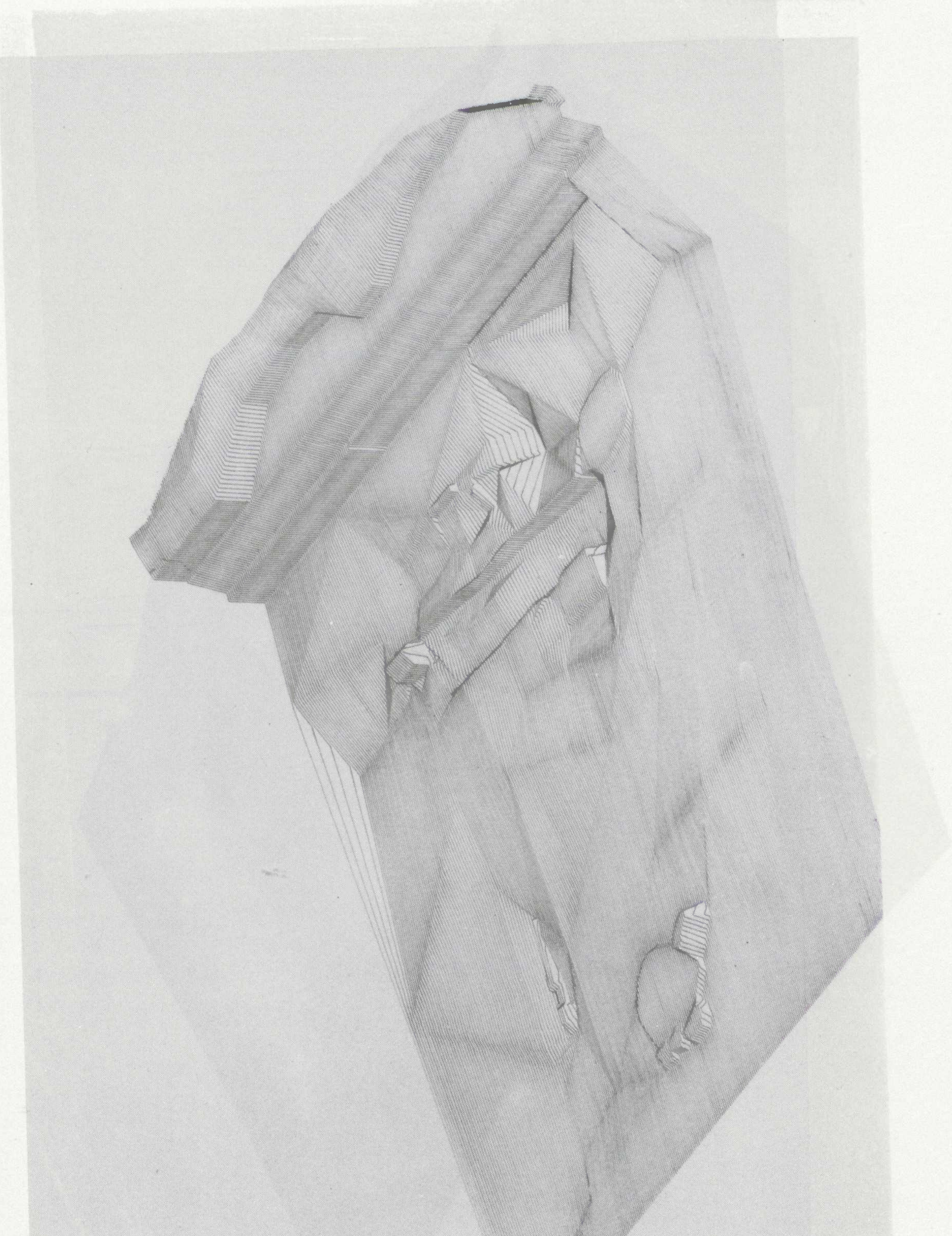

Figure 7.8: The same from another point of view

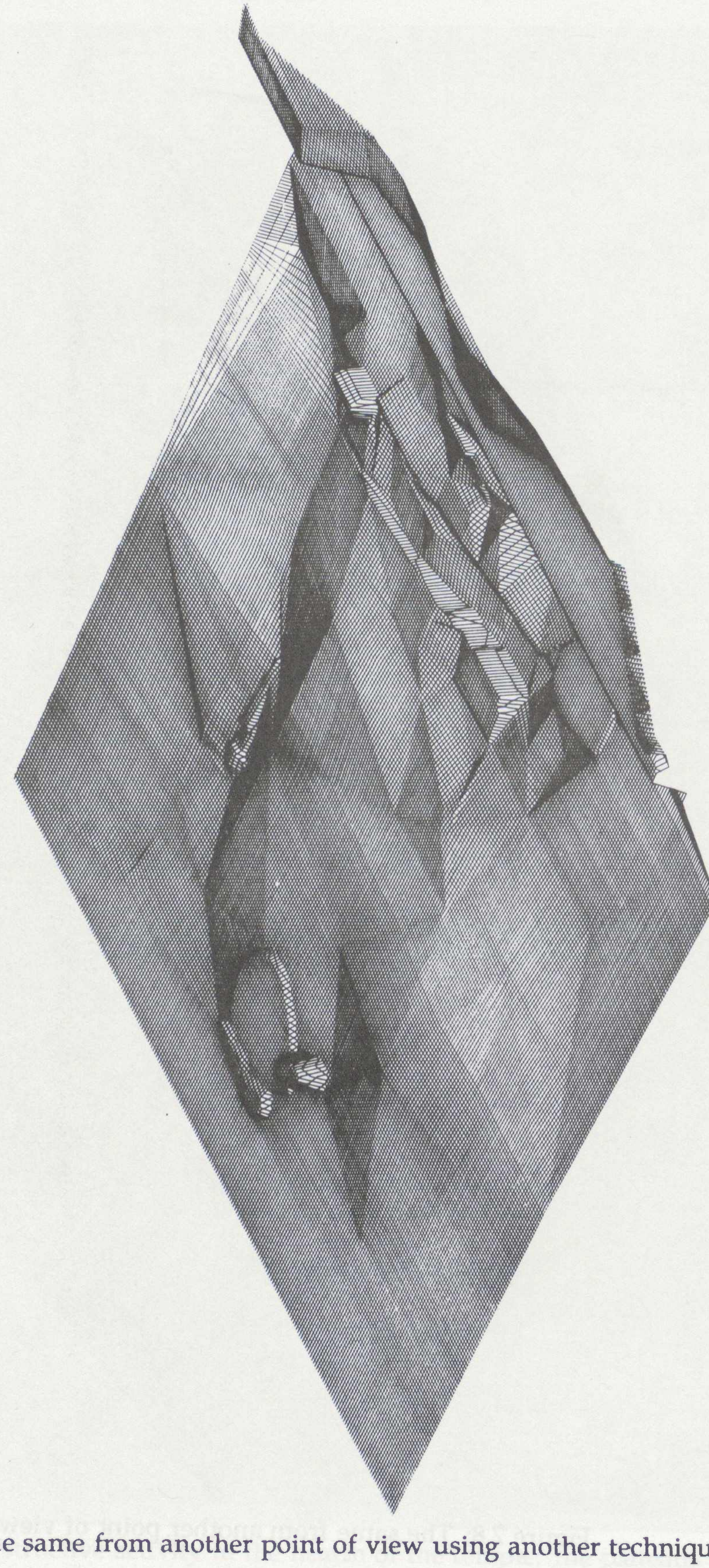

Figure 7.9: The same from another point of view using another technique of plotting

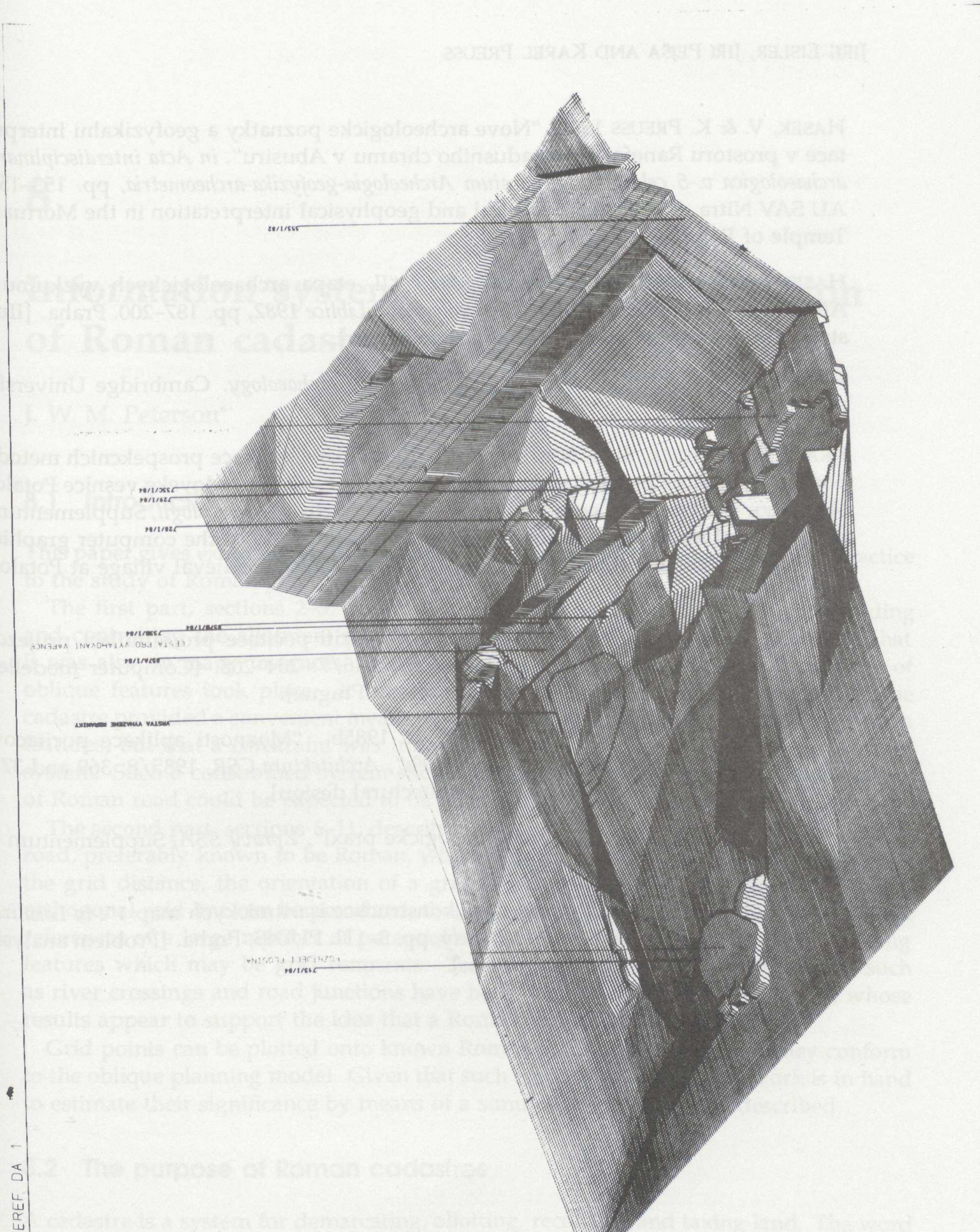

Figure 7.10: Destructive activity in the hearth of the temple: an early stage. The findings shown in their positions (represented by the lower ends of lines or by polygons, if consisting of more pieces). An example of the linking between the digital model (data related to architecture) and the database (data showing the positions of findings). plotting

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