21

Towards a virtual archaeology

Paul Reilly

(IBM UK Scientific Centre, Athelstan House, St. Clement Street, Winchester, SO23 9DR)

21.1 Paper and paper-like interfaces in archaeology

There is a long tradition of recording archaeological contexts. Early accounts are typically a bald statement of the kind: 'a Roman floor was found.' Later, longer textual descriptions appear. The correctness and truth of the observation or interpretation was confirmed by the personal standing of the reporter (cf. Hodder 1989). The more cautious added weight to their view by including another *equally good sort* as a witness. So for example Sir Richard X would describe how he uncovered the remains of Pongo man in the presence of the Reverend Y. Gradually, the introduction of greater amounts of detail and illustrations enable comparisons to be drawn. In effect, they came to be regarded as much more objective descriptions. Photographs were then introduced as proof. Unfortunately, photographs are not always adequate to show subtle differences between, for example, light brown compact sand and loose light brown soil. Nevertheless, photographs have come to be regarded as important supporting evidence to interpretations. These methods, it must be realised, were constrained by the limitations of the available technology. That is a paper interface.

The problem confronted is that of projecting aspects of a three-dimensional space on to a two-dimensional plane. This limits the effectiveness of these tools. Nevertheless, they are founded on a long tradition of convention and are useful records. Of course, scale drawings and black-and-white photographs also have the major attraction of being comparatively cheap to mass reproduce.

It is not surprising that the first computerised systems for handling and recording archaeological contexts have inherited many of the characteristics of the traditional paper interfaces (e.g. Alvey 1989, Rains 1989, Stančič 1989, Weiss 1989, pp. 314–317). However, while the excavation plan has the merit of having a direct bearing on some naturally occurring stratigraphic interface, either the top or the bottom of some context or other, the purpose of the sectional profile is much more difficult to understand. Decisions about where to place sections are arbitrary in relation to the archaeological context. Although profile-drawings are sometimes useful for delineating the excavator's interpretation of where one context ends and another begins, if the feature is not symmetrical then a section must miss details. It is a biased and partial record, which is potentially misleading. In my experience, non-archaeologists find section-drawings very difficult to comprehend, often prompting the question: "Why do you do it?"

21.2 Virtual archaeology

What does the term *virtual archaeology* mean here? The key concept is *virtual*, an allusion to a model, a replica, the notion that something can act as a surrogate or replacement for an original. In other words, it refers to a description of an archaeological formation or to simulated archaeological formation. (A simulated data set will normally be shaped by the criteria used for recording an actual formation.) The problem is therefore to identify the quintessential components of the archaeological formation under investigation. All have implications for data representation and information handling.

21.3 Impact of technological innovations

Developments into two technologies in particular are creating a climate which could herald major improvements in what and how archaeological material is recorded, structured, analysed, presented and disseminated. These are hypertext, or integrated multi-media systems, and solid-modelling. Both embody techniques for representing and exploring data.

21.3.1 Excavation simulation

In June 1989, Sebastian Rahtz presented a paper entitled *A resource-based simulation: the Southampton-York Archaeological System*, at the Dynamic Text Conference, Toronto, in which he reviewed the Southampton-York Archaeological Simulation System (SYASS). The stated aim of the SYASS project was "to develop a simulation system to give students insights into the strategic decisions involved in planning and carrying out an archaeological excavation, with special reference to the costs of different strategies and the return in terms of different types of information."

The original idea was to produce the archaeological equivalent of a flight simulator, not to simulate an archaeologist digging a site (O'Flaherty *et al* 1990). The problem was therefore to encapsulate an archaeological excavation in a teaching program. Two key issues had to be confronted before this work could begin: "what is excavation?" and "why simulate?"

The answer to the second question is rather more straightforward than to the first. In principle, simulated excavation is attractive because real excavation is destructive, expensive and slow; further, students do not get training in archaeological management and in any case most students will not become excavators.

The answer to the question "what is excavation?" involves many sub-questions such as "what is a site?" and "what are the questions being asked?" Most importantly here, there are issues of procedure: the benefits of utilising particular techniques for non-destructive survey, research design, detailed recording, analysis and synthesis.

The real question is therefore "what are we simulating?" SYASS is not simulating an archaeological site, it is simulating a British Level 2 or 3 archive. To go beyond this requires a deeper analysis of archaeological excavation and its dependencies on the technology of excavation and recording, particularly those contingent on the limitations of the two-dimensional paper-like interface. This is not to decry the SYASS concept. What I am trying to grasp at is the possibility of simulating archaeological formations and the possibility of developing new excavation procedures.

One problem brought out by Rahtz in his status report was that SYASS confronted students with concepts like context, spit, phase, horizon, locus and so on before they had ever been on an excavation. To those not yet familiar with the finer points of trench credibility, such concepts can at best register as vague impressions on the mind or, even worse, meaningless jargon.

The system I have in mind will help users obtain a clearer idea about these entities without recourse to actual excavation. The idea is a natural successor to the simulation studies of Irwin Scollar (*inter alia* Scollar 1969) and his hypothetical magnetometer surveys and Dick Spicer and Mike Fletcher's topography simulator, Clonehenge (Fletcher & Spicer 1989).

It may turn out that in many cases we do not need to record in much greater detail than we already do. We can, however, pose and try to answer such questions as: "to what level of detail can we record?" or "at what level of detail must we record?" The overall objective of such computer-based systems should be to provide insights into the understanding of archaeological formations by the addition of the powerful resources of the computer: a synergistic relationship.

Many of my comments are well known to the SYASS developers and will be partially met by planned extensions to the system, such as the utilisation of non-schematic graphics like videodisc and reconstructive modelling.

21.4 Solid modelling to reconstruct the monument

So, how far have we progressed on the road to three-dimensional modelling in archaeology? Well, for several years now, advances have been made in the application of presenting monuments through solid modelling techniques, and there is a growing number of published examples (*inter alia* Anon 1990, Arnold *et al* 1989, Cornforth & Davidson 1989, Moscati 1989, Reilly 1988a, Reilly 1989, Reilly & Shennan 1989, Smith 1985).

The motivation behind the earliest projects was essentially to explore the potential of this sort of technology to illustrate monuments. Equipped with a detailed model and some facilities with which to view all its many aspects, these first projects were forced to restrict the number of views generated because of limited processing resources. Even so, archaeologists were surprised by the some of the insights they obtained about the use of space by ancient architects for example (Reilly 1988b, p. 29). Gradually, it has become practicable to produce larger numbers of views within the same time brackets while incorporating greater realism in the effects modelled (e.g. perspective, highlights, textures, shadows, reflection, refraction and the current moves to radiosity).

From the simple time-step walk-through (e.g. Smith 1985), archaeologists have progressed to the production of fully animated tours of solid models to enable people to appreciate the scale and relationship of elements within a limited number of archaeological remains (e.g. Reilly 1988b, pp. 28–36). A notable recent example is a three-minute animated tour of a model of the now destroyed Edo Castle in Tokyo, rendered at the IBM Japan Tokyo Research Laboratory for Japan's NHK (Nippon Housou Kyoukai) TV. This beautifully detailed model is a reconstruction of Edo castle of the Tokogawa period (1603–1867), the period of the Shoguns (see Miyata 1990, Nikkei Computer Graphics 1989a, 1989b).

21.4.1 Roman Pompeii

At Pompeii, the WINchester SOlid Modeller (WINSOM) produced at the IBM UK Scientific Centre is helping visitors to understand better the world-famous remains of the Roman city that was buried when the volcano Vesuvius erupted in A.D. 79. Today, the visitor can begin to explore this ancient city before actually setting foot in the eerily silent ruins. As a result of a joint project between IBM Italy and FIAT Engineering (called *Consorzio Neapolis*), what is possibly the most advanced archaeological information centre in the world is housed in a brand new study complex at Pompeii. From PS/2 workstations, connected to an IBM 3090-150E mainframe through token rings, researchers have access to the most complete set of photographs, plans, sketches, archaeological reports, diaries and finds catalogues connected with the site which has ever been assembled.

At Pompeii there has been a heavy reliance on graphics as an interface to the Pompeii archives. The most important navigation method through this colossal hypertext databank is by using digitised maps of the city and its environs (Gullini 1989, Martin 1988, Moscati 1989, Zingarelli 1989).

Seated at a workstation, the visitor can be presented, for instance, with a plan of a Roman villa on the screen. By clicking a cursor on part of a room in one of the villas, scanned photographs of the room, or the frescoes on its walls, will be displayed. Help panels explain in plain English or Italian what the building was used for and how it was constructed. Technical words like 'hypocaust' are highlighted; by clicking on the word, a window containing a concise account of Roman central heating systems will appear. The user is prompted to look once more at the pictures of the room containing the heating system, to try and relate the explanation back to the actual building. Naturally, nothing can be seen of the heating system because, as the building is so well preserved, the system is still buried below the surface of the floors and walls. Here solid modelling comes to the rescue. The photograph is replaced by a corresponding view of a model of the same room. However, part of the model's floors and walls have been removed, thus revealing the hypocaust.

Similar principles are being applied in other major Italian programmes such as the SITAG project on Sardinia (Soprintendenza Archeologia Per le Provincie di Sassari e Nuoro 1989, p. 31).

Impressive though such enormous projects are, a gap still remains between the interpretation and the original data. It is not readily apparent how one gets from the dig to the interpretation.

Reconstructing archaeological sites is just one aspect of archaeological research. Understanding the subtleties of the raw data is, if anything, even more important to archaeologists themselves. By constructing detailed models of the excavated material, archaeologists can re-excavate the site and search for evidence which escaped attention during the actual dig. Research of this kind clearly has major implications for how archaeological excavation and interpretation is taught as well as performed.

21.5 Early attempts to model archaeological contexts

Lately, attention has begun to be focused on modelling archaeological formations as they appear in the field. The challenge is no longer only to model buildings with simple geometry, but to model those amorphous humps, bumps and hollows, typically found in the course of fieldwork.

21.5.1 Bronze age Klinglberg-St.Veit

WINSOM solid modelling methods were introduced into the investigation of the Early Bronze Age settlement site at Klinglberg-St.Veit in the Austrian Alps (Reilly & Shennan 1989). Normal methods of planning, levelling and sections through features, such as post-holes and pits, were used.

Trying to build three-dimensional models from the recorded data was not possible. Although the excavators used the highest current standards of excavation, survey and recording, it could not be said that they had produced a true three-dimensional record. It has to be most archaeological excavation recording has still a long way to go yet before excavators can claim that they record archaeological features in a manner that allows their full three-dimensional form to be reconstituted.

The problem is that, at best, only top surfaces are recorded adequately. However, one of the interesting problems with the Klinglberg data is the relationship between the patterning of the material in the spatially extensive deep layers and that in the intrusive features immediately below them. Having only plan records of the cuts of these features, the digitised outlines of the cuts were extruded to form solid prisms. These prisms are then intersected with a solid model of the overlying deposits, which have been sub-divided into box-contexts. Colour-codes signify the levels of whatever property is being investigated. Slices can then be cut away from the sides (or from the top) of the modelled excavation to reveal the internal details of the trench. By such means one can determine whether there are any visual correlations between the distribution of, for example, objects in the features and the overlying layers, and whether they are worth exploring further.

The method is very powerful, but having to work with the planned outlines of features on coursely modelled startigraphic surfaces is somewhat limiting.

21.5.2 Medieval Mathrafal

The production of detailed WINSOM solid models of archaeological topography was demonstrated at Mathrafal where a blanket of survey data was used to help analyse the site's surface morphology and compare it with information derived from non-destructive geophysical surveys (Arnold *et al* 1989). It is technically possible to extend the principle of topographic modelling to the level of the context. The problem is not that of collecting the data but of persuading excavators that this is in fact the case.

21.6 Recent attempts at excavation simulation

All these ideas — teaching simulation systems like SYASS, research simulations like Clonehenge, hypertext systems like that at Pompeii, improvements in free-form solid modelling, together with a basic flaw in the archaeological recording method — gelled together and provided the motivation for a new project to build a three-dimensional model of a realistic, but simulated archaeological formation, containing layers, pits, post holes, cuts, recuts and so forth. The aim of this research is to demonstrate that archaeologists can produce realistic records of the data they inevitably destroy in the course of excavation. Once in this form it is susceptible to novel methods involving transformations and interactions which open the way for new knowledge to be created and insights about the nature of three-dimensional deposits and their recording to be gained.

Grafland, as this simulated excavation is called, consists of a series of layers with various features cut into them (Figs. 21.1 to 21.4 inclusive). The layers were manufactured by creating hypothetical profiles, which where then digitised. This is equivalent to surveying along a transect. The layer is defined initially as that volume between the measured surface and an arbitrary datum plane at some depth below. The top of the layer(s) immediately underneath form the bottom of the previous layer and define its other side. Layers can be isolated using constructive solid geometry (CSG) operators. Incidentally, the logical stratigraphic order of the deposits in the formation is largely implicit in the model definition. The model could therefore be linked to a Harris Matrix or phasing program, so that context sequences and connectivity can be studied. Knowing all the properties of Grafland, it becomes possible to devise different exploration scenarios to see how far they can facilitate a reconstruction of the site, the activities on the site and post-depositional processes operating at the site.

Most of the cut features in the Grafland model are composed of compound CSG shapes, such as cylinders and spheres or parts thereof. However, some of the contexts have been modelled as if a real irregularly shaped feature had been found with artefacts deposited it. Of course, much more complex models are possible.

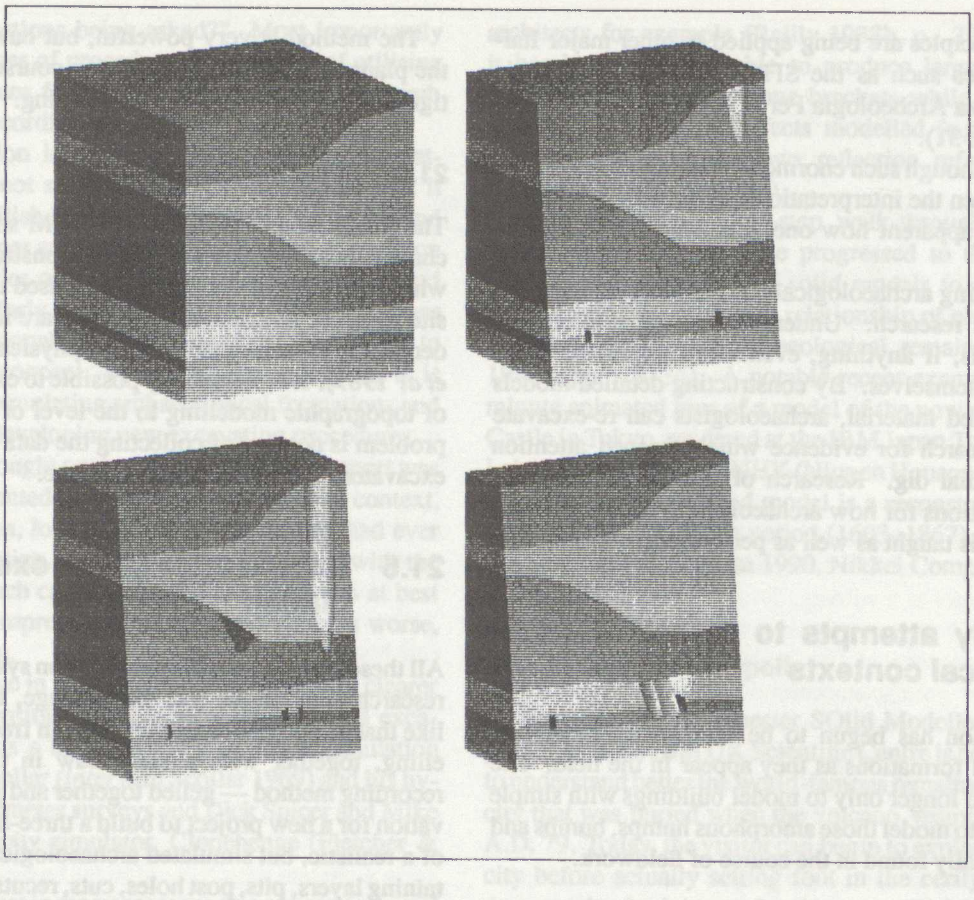

Figure 21.1: Removing slices from the side of Grafland

21.6.1 Grafland solid model animation

A Grafland animation sequence has been generated to illustrate the composition of the model excavation. Briefly, the animation shows a flat green open space, perhaps a field, which gradually falls downward leaving a block of ground, which represents the simulated excavation volume, floating in space. The simulated formation is spun on its axis to show the different shapes of the major layers exposed in the profiles. Next, slices are cut away from one side, and later from the top, showing sections through the various pits and post holes cut into the layers within the formation. In another sequence, each of the major layers is removed to reveal the buried contexts cut into the surface of the next major layer below. Each new layer surface is exposed in the order an archaeologist would meet them, that is the basic stratigraphic sequence. After this, the major layers are then ignored and only the cut features are visualised. At one point in the animation, these contexts are built up in reverse order. The current final sequence involves a zoom towards a feature, which include a hypothetical artefact assemblage in situ, to illustrate the fine level of detail that can be recorded.

21.6.2 Grafland

The animation brings out several key points. To begin with, the multiple views of the model demonstrate the principle of constructing true three-dimensional solid models of archaeological formations is feasible and provides a superior record and database for further research. Allied to this, archaeologists can present larger volumes of complex data to a wider audience in more meaningful ways. This should enable archaeologists to explain better how their interpretations derive from the data. Perhaps most important of all, data exploration and analysis are promoted still further. Visualisation can be exploratory — in the sense that the researcher may pan through the data looking for loci of activity and other evidence. In other words, searches can be spatially organised, with the structure of the solid model being exploited as an efficient high-level spatial index. Conversely, the visualisation can be more attribute directed. For example, if the modeller labels, or provides pointers to and from, component features it is possible to isolate specific and associated stratigraphic components using standard database functions. An example might be a model in which all the cut feature between layer α and layer β are isolated and displayed in order to study the different routes by which residual material could have travelled in getting from α to β. The solid model description has the additional benefit of having valuable quantitative details, such as volumetric information about contexts, implicit in the model definition.

21.7 Prospects

It seems then that the various technological and intellectual threads discussed above are coalescing. A logical extension of the hypertext concept is to integrate solid models of the kind outlined above into a multimedia environment, not only as theoretical reconstructions, or even three-dimensional models of the recorded features, but as user interfaces for data interrogation and navigation.

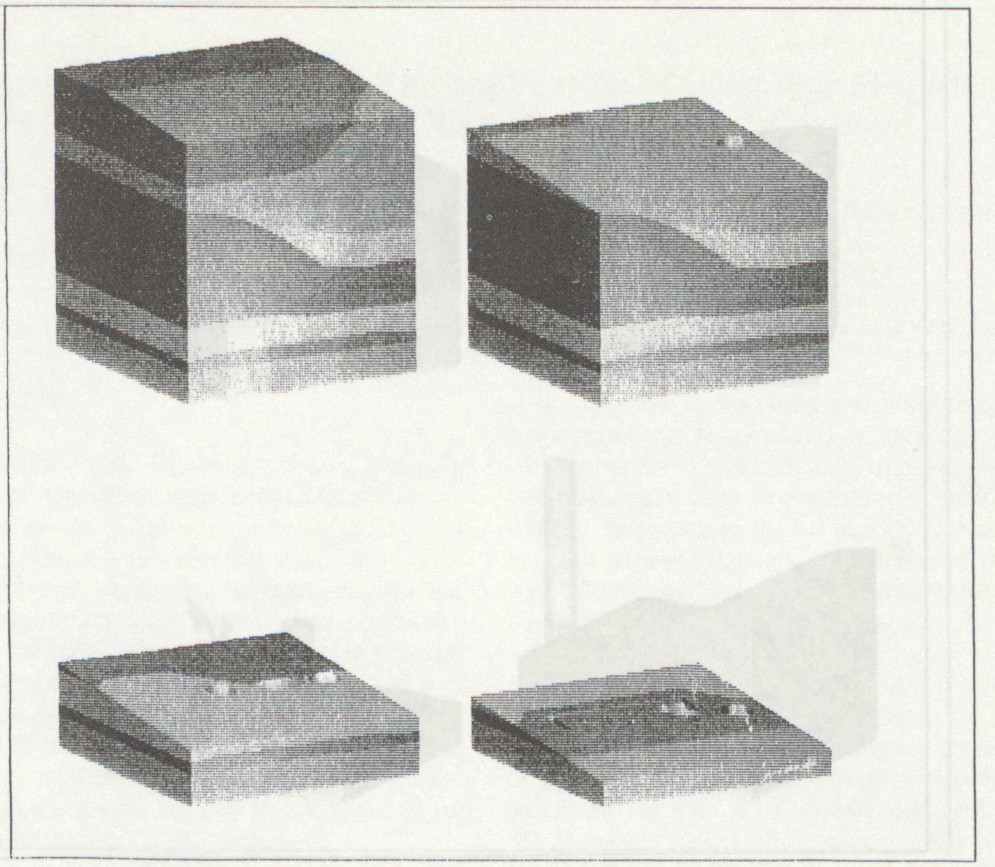

Figure 21.2: Removing slices from the top of Grafland

Here we can provide hyperlinks between the solid model and other data sets associated with the object of interest (e.g. image, audio, video, DVI and text). A three-dimensional cursor could provide one possible interface, allowing users to *point* at part of the model to discover what is being looked at and whether further information is available.

The convergence of these technologies, solid modelling and hypertext, raises many interesting avenues which need to be explored in order to make the one archaeological record acceptable to those interested in preservation through recording, research, education and presentation.

In the area of *digital solids*, in which free-form solids are modelled, we are witnessing exciting new developments. Already, modellers can extract feature data from sets of medical scans (e.g. those produced in CAT) to build three-dimensional models of patients (e.g. Tyrell *et al* 1990). Medical tomographic data is analogous to the geophysical scans produced from devices such as the 'Ground Pulse Radar', which is apparently capable of registering even small archaeological features many metres below the ground (Addyman & Stove 1989). However, there are two significant differences between the nature of the data embodied in medical and archaeo-geological scans, each of which represents a considerable challenge to routinely modelling and analysing archaeo-geophysical formations. First, the sheer volume of data is enormous and is already pushing hardware and software processing requirements. Second is the problem of feature recognition and extraction. Building models from scans of patients is made simpler because there already exists a considerable amount of *a priori* knowledge about the nature of human physiology.

At the moment feature extraction is difficult with straightforward geometric models (e.g. Jared 1989). Looking for meaning in a virtual sea of heterogenous three- (or more)-dimensional data is one of the key problem-areas currently being addressed at the leading edge of the modelling world. Archaeologists should look forward to progress being made in this area with particular enthusiasm.

In the meantime, Grafland-like models might be used as controlled data sets to devise and assess different excavation, recording and analysis scenarios. They may even prove helpful in evaluating the strengths and weaknesses of pattern recognition procedures.

Bibliography

ADDYMAN, P. V. & C STOVE 1989. "Ground Probing Impulse Radar: an experiment in remote sensing at York", *Antiquity*, 63: 337–342.

ALVEY, B. 1989. "Hindsite", *Archaeological Computing Newsletter*, 19: 4–5.

ANON 1990. "Remaking History One Pixel at a Time", *IEEE Computer Graphics & Applications*, July: 3–6.

ARNOLD, C. J., J. H. HUGGETT, P. REILLY, & S. SPRINGHAM 1989. "Mathrafal: a case study in the application of computer graphics", *in* Rahtz & Richards 1989, pp. 147–156.

CORNFORTH, J. & C. DAVIDSON 1989. "Picturing the Past", *Archaeological Computing Newsletter*, 19: 6–10.

FLETCHER, M. & R. D. SPICER 1989. "Clonehenge C-Coded", *Archaeological Computing Newsletter*, 16: 10–15.

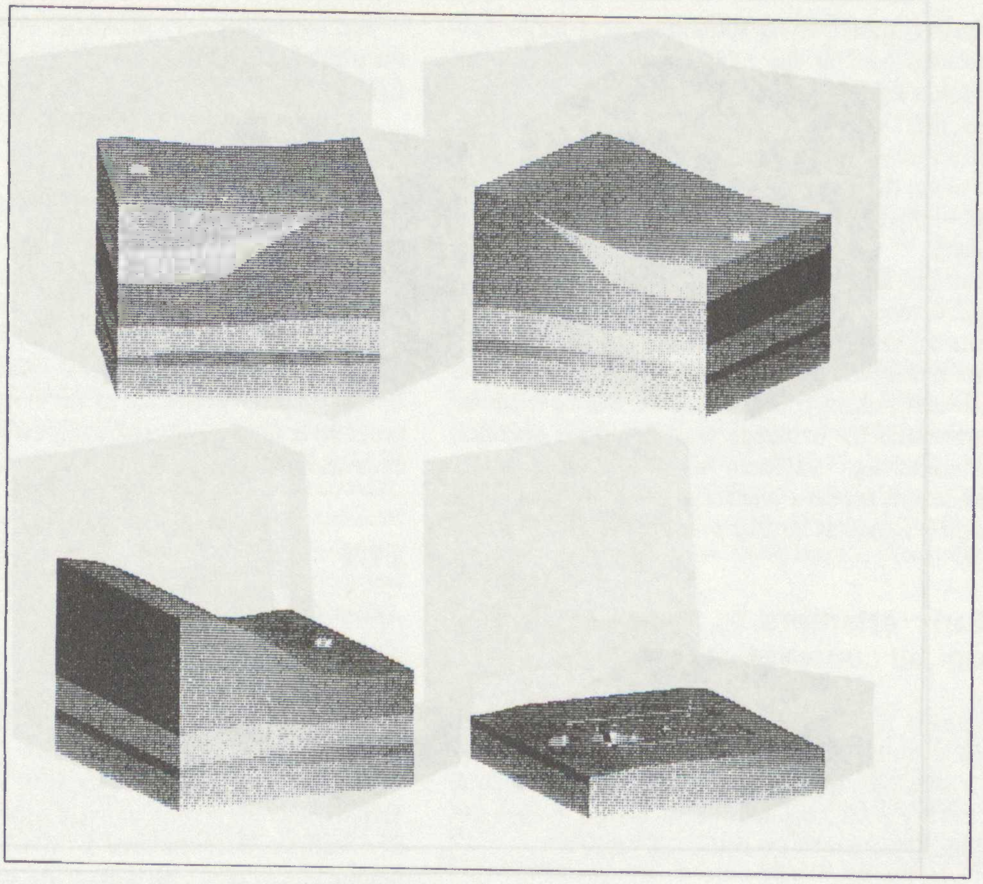

Figure 21.3: Grafland layers

GULLINI, G. 1989. "Il Computer per la Rappresentazione del Manufatto Archeologico", *Rivista IBM, XXV*, 1: 42–44.

HODDER, I. 1989. "Writing Archaeology: site reports in context", *Antiquity*, 63: 268–274.

JARED, G. E. M. 1989. "Recognising and Using Geometric Features", *in* Woodwark, J. R., (ed.), *Geometric Reasoning*, pp. 169–188. Oxford University Press.

MARTIN, J. 1988. "Computing for Art's Sake", *Datamation*, December: 86/9–86/13.

MIYATA, K. 1990. "A Method of Generating Stone Wall Patterns", *Computer Graphics*, 24 (4): 387–394.

MOSCATI, P. 1989. "Archeologia e Informatica: l'esperienza di Neapolis", *Rivista IBM. XXV*, 1: 24–27.

NIKKEI COMPUTER GRAPHICS 1989a. "Art and Presentation", *Nikkei Computer Graphics*, 12: 74–79.

NIKKEI COMPUTER GRAPHICS 1989b. "Fujita Industrial Company and IBM Tokyo Research Laboratory Work Together to Reproduce Edo Castle as it was 400 Years Ago", *Nikkei Computer Graphics*, 10: 102–103.

O'FLAHERTY, B., S. P. Q. RAHTZ, J. RICHARDS, & S. SHENNAN 1990. "The Development of Computer-Based Resources for Teaching Archaeology", *in* Cacaly, S. & Losfeld, G., (eds.), *Sciences Historiques, Sciences du Passe et Nouvelles Technologies d'Information: bilan et évaluation, Actes du Congres International de Lille (16–17–18 Mars 1989)*. CREDO, Universite de Gaulle, Lille III, Lille.

RAHTZ, S. P. Q. & J. D. RICHARDS, (eds.) 1989. *Computer Applications and Quantitative Methods in Archaeology 1989*, International Series 548, Oxford. British Archaeological Reports.

RAINS, M. 1989. "Computerising the Plan Database: the Aegis system", *Archaeological Computing Newsletter*, 21: 1–2.

REILLY, P. 1988a. *Computer Analysis of an Archaeological Landscape: medieval land division on the Isle of Man*. British Archaeological Reports, Oxford. British Series 190.

REILLY, P. 1988b. *Data Visualisation: recent advances in the application of graphic systems to archaeology*. IBM UK Scientific Centre Report 185, Winchester.

REILLY, P. 1989. "Data Visualization in Archaeology", *IBM Systems Journal*, 28 (4): 569–579.

REILLY, P. & S. J. SHENNAN 1989. "Applying Solid Modelling and Animated Three-Dimensional Graphics to Archaeological Problems", *in* Rahtz & Richards 1989, pp. 157–166.

SCOLLAR, I. 1969. "A Program for the Simulation of Magnetic Anomalies of Archaeological Origin in a Computer", *Prospezioni Archeologische*, 4: 59–83.

SMITH, I. 1985. "Romans Make a High-Tech Comeback: Sid and Dora's bath show pulls in the crowd", *Computing*, June: 7–8.

SOPRINTENDENZA ARCHEOLOGIA PER LE PROVINCIE DI SASSARI E NUORO 1989. "S.I.P.I.A.— Progetto S.I.T.A.G. (Sistema Informativo Territoriale Archeologico Gallura)", *in Archaeologia del Territorio. Territorio dell'Archeologia: immagini di un'esperienza di catalogazione informatica dei beni culturali della Gallura*. Tempio Pausania, Chiarella–Sassari.

STANČIČ, Z. 1989. "Computervision: producing intra–site plans", *Archaeological Computing Newsletter*, 20: 1–10.

TYRELL, J., F. YAZDY, M. RILEY, & N. WINTERBOTTOM 1990. "CARVUPP: Computer–Assisted Radiological Visualisation Using Parallel Processor". Paper presented at the Transputer Applications '90, 11–13 July, 1990 at the University of Southampton.

WEISS, A. 1989. "The Compass System", *in* Rahtz & Richards 1989, pp. 295–318.

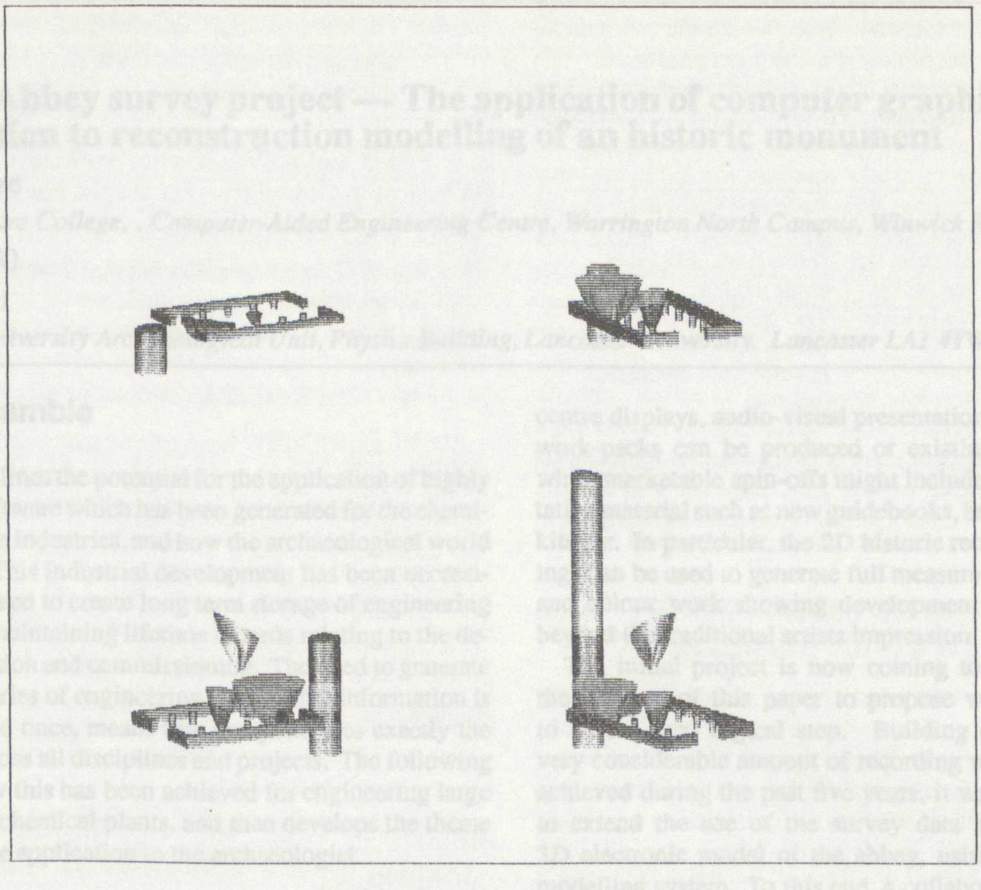

Figure 21.4: Grafland cut features

ZINGARELLI, D. 1989. "Baldassare Conticallo: cronaca di un progetto", *Rivista IBM*. XXV, 1: 30–39.