24

Visualisation of sherd movement in the plough zone

Madhumita Sen-Gupta

Susan Laflin

(Centre for Computing and Computer Science, P O Box 363, University of Birmingham, Birmingham B15 2TT)

Peter Reynolds

(Butser Ancient Farm Trust, Horndean, Hampshire)

24.1 Introduction

As a result of the experiments which Peter Reynolds (Reynolds 1988) discussed at the 1988 CAA conference, the database of sherd information, accumulated over a period of nine consecutive years, provided a rich source of numerical data giving scope for an analysis package which could aid in the visualisation of the sherds and their movements.

The resulting database is composed of a collection of thirty-six sherd records, each one constructed from a sequence of annual recordings (1981 to 1988). The set of recordings associated with a particular year within a given sherd record, supplies information concerning the sherd's location and spatial disposition within the ground (i.e. its orientation, deflection, *etc.*) for that year.

Table 24.1 illustrates a sherd record which has been extracted from the original database.

In order to produce such recordings, the sherds were artificially manufactured from plastic resin, each one encasing an identification number (for uniqueness) and a longitudinal bar magnet (for detection of its orientation and deflection within the ground). All sherds were assumed to have a common weight and a common size, both of which remained constant throughout the experiments (i.e. it was assumed that the sherds had not disintegrated). In fact, the only difference between the sherds was in their shape. Sherds were randomly assigned and moulded into one of four possible shapes: diamond, square, circle, or shield.

Subsequent to the production of this database of recordings noted between 1981 and 1988, Peter Reynolds approached the Computer Science department of Birmingham University requesting a user-friendly software package that could visually represent in three-dimensions all the movements (including lateral, vertical, angled, rolling, pitching, inversion, *etc.*) of the sherds found from the experiments, with a facility for viewing the sherds altogether as well as individually. In addition, specific statistical information concerning the view was required to be accessible.

Hardware constraints imposed upon the requested software included the ability for it to be executable, or runnable, on an Amstrad 1640, fitted with EGA graphics card, using a traditional command-driven form of interface with interaction between user and system via a keyboard.

Performance constraints, such as timing of execution of the software, were naturally confined to the limitations of an Amstrad 1640. However, since the package would be required to work upon a substantial amount of data, a reasonable memory capacity had to be available in order to store the database as well as the executable software.

The only other constraint upon the required software regarded the necessity of the software being user-friendly, as it could not be assumed that the final users of the package would be computer-literate.

24.2 Design of the software

The design of the resulting software is a direct reflection upon the functional requirements imposed. These were, as briefly mentioned in the previous section, to:-

1. Produce graphical representations, in three dimensions, of the movements of all the sherds recorded in the database.
2. Enable the user to specify an individual sherd and trace out its total movements within a volume of ground.
3. Supply the user with certain statistical information with respect to the graphical display produced. For example, within the graphical output showing all the movements for a single sherd, related statistics would include the average distances the sherd had travelled in all the possible planes of movement and the frequency of the sherd appearing on the surface.

These basic requirements were then elaborated upon, with further consideration given to the various forms of displays that may be produced, the way by which they may be produced and any other facilities that would help improve or enhance the displays and the total package (database + graphical displays) in general.

The outcome of this expansion is summarised by the detailed schematic overview of the resulting system, Fig. 24.1.

Also, a further, but necessary, requirement was for the software package to be able to work on different data bases. For this reason, the resulting software is a composition of two separate programs. One program deals with the initialisation of a new data base, storing the first sherd record of the data base only. The other program deals with the initialised data base, allowing the user to make additions and modifications to it, as well as providing visualisation of the existing data. In fact, currently, several sets of data are being processed at Butser using the resulting software.

24.2.1 Description of options and Screen outputs

24.2.1.1 Add data (option 1):

allows the user to add new sherd records to an existing database.

Sherd No	East	South	Depth	Attitude	Year
132	000	200	5	H N-S U	81
	+020	339	10	V E-W S	82
	058	216	9	A(E-W) E-W U	83
				Data missing	84
				Data missing	85
				Data missing	86
				Data missing	87
				Data missing	88

Table 24.1: Sherd record from original database

24.2.1.2 Update data (option 2):

allows the user to modify data on sherd records already in the database in the following ways:-

- **Alter record (option 2.1)** — corrections may be made to data already recorded.
- **Delete record (option 2.2)** — remove a sherd record from the database.
- **Add to record (option 2.3)** — add details for extra years to the record of an existing sherd.
- **Return to main (option 2.4)** — return to main menu.

24.2.1.3 Quit (option 4):

terminates the program.

24.2.1.4 View data (option 3):

allows the user to choose from the various visualisation options, namely:

Show all (option 3.1) Allows the user to select from the entire range of sherd records within the database, subject to the following:

- **Entire data** — displays the whole database.
- **Data by shape** — selects data for one of the four shapes, diamonds, squares, shields or circles.
- **Data by years** — selects data for the specified range of years.

In this representation, sherds are depicted as single dots, outlined in the same or a different colour. The starting position for each sherd is indicated by a white dot, outlined in the sherd's symbolic colour. All other positions for the sherd are indicated by its symbolic colour and also outlined as such. Lines connecting the annual positions for each sherd are also shown in the sherd's symbolic colour.

A solid line means that the two sherd positions at either end of the line have been calculated using actual data. When data is missing for one or more years, the data values on either side of the gap are joined with a dotted line.

The symbolic colours for the sherds are as follows:

- *Diamond* shaped sherds in **red**.
- *Square* shaped sherds in **green**.
- *Shield* shaped sherds in **magenta**.
- *Circular* shaped sherds in **blue**.

For each of these options, the user may then choose one of the four possible viewing planes:

- *Scaled cubic.* The area used in the study is shown as a three-dimensional cube with the same scale in each of the axes. This was considered important so as to give a *realistic* view of the data. Different shapes of sherd are indicated by different colours and the example chosen in screen 1 of the figures displays all the available data with the obvious problems caused by the sheer quantity of data. It is immediately obvious that the vertical movement is small and, with the exception of two sherds, the overall movement is also small.
- *Standard cubic.* This takes a cube which fills the screen and applies a different scale to each axis to display the data in it. This makes maximum use of the available display area, although with some loss of realism, and so allows more detail to be seen, even in the example shown in screen 2 where all the data is displayed. When displayed in colour, it can be seen that the shape of the sherd has little effect on the distance moved. Screen 6 shows circular sherds only and the smaller amount of data makes the diagram even clearer.
- *Elevation.* This is a two-dimensional display where the axes represent depth versus year number. Again, colour is used to indicate the shape of the sherd. In 1981, all the sherds were placed at a depth of 5 cms and the diagram labelled screen 3 shows the variation of depth with year. Had there been any clear pattern of depth-variation, either over time or for one particular shape of sherd, this would have shown in this mode of display. For this particular data set, there was no obvious variation with sherd-shape. For the first two or three years, the variation with depth remained small, but after that sherds could be found throughout the ploughzone, from the surface to the full depth of 30 cms. Screen 5 shows square-shaped sherds only and is similar to screen 3.
- *Plan.* This is another two-dimensional display, but this time the axes are horizontally the E-W distance and vertically the N-S distance. Screen 4 shows an example of this for all shield-shaped sherds. Had there been an overall movement in one direction, this would have been evident from this view, but once again this set of data shows little overall movement.

For each of these options, the user may view the output interactively or non-interactively. For interactive mode, the output is displayed step-by-step, either one year at a time or one sherd at a time. Screens 7 to 11 show interactive output, year-by-year, for a plan view of all the data. 1981 shows the initial placing of the sherds over a rectangular grid (and at a constant depth of 5 cms although this is not shown in this view). Then the movement over successive years is built up over the later screens.

```
 Add data(1)  ___Update data(2)_______ View data(3) Quit(4)
                |                  |       |
                |->  Alter record (2.1)    |
                |->  Delete record (2.2)   |
                |->  Add to record (2.3)   |
                |->  Return to main (2.4)  |
                            |              |
                      select sherd         |
        ___________________________________|
        |          |           |           |
 Show all  Show single  Display table  Vector form  --- -|
   (3.1)      (3.2)        (3.3)          (3.4)          |
     |          |                                        |
     |  | --- -- select sherd      |->  average dists.   |
     |  |                        |->  frequency at       |
     |  |--> Magnify / Retain --|        surface         |
 | --- |  |________|                                     |
 |   v                                                   |
 |   (INTER-ACTIVE / NON-INTERACTIVE mode) < ---  ---  --- --|
 |
 |      ____________________________________________
 |   Interactive       Non-Interactive   Return
 |      (3.1.1)            (3.1.2)       to main
 |      (3.4.1)            (3.4.2)
 v
 (Selection of VIEWING PLANE)
     ______________________________________________
     Plan      Elevation   Standard cubic   Scaled cubic
   (3.1.1.1) (3.1.1.2)    (3.1.1.3)        (3.1.1.4)
   (3.1.2.1) (3.1.2.2)    (3.1.2.3)        (3.1.2.4)
      | - ->- - - > - - - - -<- - - < - - - - |
                           |        | ---  --- ---   --- -
                           |        | ---  --- > Magnify / Retain
                           |        | ---  --- -< --- -|
                           v
     ____________________   ________________________
   Entire data    Data by shape   Data by years  Return
                           |                     to main
 Diamonds only  Squares only  Shields only  Circles only
```

Figure 24.1: Sequence of options

Screen 12 shows a similar approach on the standard cubic output. Non-interactive output displays the whole set of data without a pause.

Show single (option 3.2) This allows the user to select one particular sherd record from the database and display the sherd's movements using the standard or scaled cubic output.

Viewing the movement of one specific sherd conveys more detailed information. Each year the sherd is characterized according to its location within the ground, the direction it points in, its tilting (deflection) in the ground and whether it is face-up, face-down or vertical.

All this information is represented by the following rules:

1. The centre point for each shape gives the sherd's location.
2. The direction in which the sherd is pointing is shown by a small white circle on one of the vertices. This must be viewed relative to the compass.
3. Tilting of the sherd may only be judged by inspection (the vertical disposition, however, is clearly apparent).
4. The sherd is drawn in its symbolic colour, with the following conventions: face-up sherds are shaded in solid colour, face-down sherds are line-filled and vertical sherds are drawn in outline.
5. The sequence of movements is represented by annotation of the sherd positions numerically (1 representing the first position and the largest number representing the last position).
6. Sherds that appear on the surface are outlined in white and all others are outlined in yellow.

Under each diagram is placed a comment box conveying information about the display shown. For example, for a single sherd this information is about the sherd's identification number and shape.

Screens 13 to 16 show examples of this form of output.

Display table (option 3.3) This choice provides the user with an overview of all the sherds held in the current database, associating each sherd with its recorded shape and the total distance it has moved during the years recorded in the E–W and N–S planes, as well as in terms of depth and the overall total distance moved by the sherd spatially. For each distance field within the table, two measurements are recorded and displayed. The first measurement represents the cumulative distance value, while the second measurement, shown in brackets alongside the first measurement, represents the distance value from the original to the final position of the sherd. If, for any year within a sherd record, the data has been recorded as missing, then it is assumed that the sherd has not moved in any direction that year and its distance values are counted as zero in each direction. The purpose of displaying such a table lies in the provision of enabling the user to select sherds of particular statistical interest for later viewing.

Vector form (option 3.4) This shows the movement of all sherds in a given year as though from a common starting point. This should demonstrate any overall movement even more clearly than the plan output.

Screen 18 shows the result for the year 1982. Once again, the different colours indicate the different shapes of sherd and for this data set and mode of cultivation there is no overall movement. The program is being run interactively and so the user has the choice of viewing the results for the next year.

Screen 17 shows the non-interactive use of this output for the range of years from 1981 to 1984 and here the different colours, superimposed upon one another, indicate the different years.

24.2.2 User Interface

The interface has been designed to provide the user with as much flexibility as possible, and has been adopted because it makes the system highly robust. It is structured as a sequence of menus, each highlighting a set of options from which the user is required to make a selection.

This selection may be done using only the keyboard, or using a mouse as well as the keyboard. The choice of operating mode is made by the user in the initial stage of executing the program.

When the keyboard is used, a menu appears on the screen and the user selects an option following the rules outlined below:

- For a menu appearing horizontally across the screen, right and left cursor keys are used to select the option, which is highlighted.
- For a menu appearing vertically down the screen, up and down arrow keys are used to select the option, which is highlighted.

In either case, the user must press the return key to indicate his/her choice and start operation of the selected option.

When the mouse is used, a menu appears on the screen and the user selects an option by moving the mouse to the appropriate option box which becomes highlighted. Commencing execution of the selected option is simply done by pressing the right button of the mouse.

Naturally, where the system requires typed input, only the keyboard may be used. Validation of user response in such a case is of prime importance, and hence the system has been thoroughly tested and developed to maximise this.

A choice of sixteen colours including red, blue, black, white, yellow, cyan, magenta and light and dark shades of some of these seven colours available when developing the software, was utilised as comprehensively as possible (to enhance clarity and highlight important information in the graphical displays), and the layout for the final schematic flow of options and menus was constructed in order to maximize flexibility to the user, hence making the system user-friendly.

It should be noted that the use of colour and three-dimensionality helped to make the screen outputs effective and useful in discriminating between patterns of movement. Unfortunately the absence of colour has meant that these affects cannot be fully appreciated here.

24.3 Conclusions and Further research

From the computer scientists' point of view, the requested software has been developed and tested to provide a satisfactory performance of the system required. However, further enhancements to the resulting software may be made. For example, the use of colour coding to symbolise depth-variation of a single sherd's location within a volume of ground. During development of the software, it was intended that varying shades of the *same colour* should be employed to symbolise this depth-variation. Unfortunately, this could not be implemented since the hardware constraint of using an EGA graphics card had imposed a restriction in the *availability* of colours.

Another enhancement that would appear desirable is to provide the user with a facility to *rotate* a three dimensional view. Since this had not been specifically requested, the more necessary requirements were attended to instead.

Nevertheless, this is all from the point of view of the Computer Scientists. Far more important is how useful has the software proved for the end users? And what are the possibilities of further developments using this software? These questions may only be answered by the actual end users. Peter Reynolds is both the commissioner and principal end user of this software, so the remainder of this section comprises *his* views and conclusions upon the resulting software and its use.

The reason for the development of the software was specifically to create a graphics presentation of a large and cumbersome sequential data base in order to allow subsequent selection, analysis and comparison. In effect it comprises a relatively sophisticated three dimensional display of fixed points allowing adjustments to scale and, therefore, enhancement by distortion. Its greatest use is the facility to display both combined and individual sequences of fixed points. Built into the program as a basic requirement was the need to cross refer and provide comparative analyses between different phases of data. The overall objective is the analysis of the data bases achieved from the study of artefact movement in the topsoil (Reynolds 1989). The purpose of this study is to evaluate the topsoil as a potentially important archaeological layer worthy of detailed excavation in that the material evidence contained within it can be associated with underlying archaeological features. Artefact assemblages in and on the surface of the soil layer are argued as indicators of a site and are frequently used in field walking to plot locations. Given this, the hypothesis seeks to examine if the assemblages are infinitely spread by plough action or whether the concentration is real in the sense that travel is limited by the nature of the cultivation. Unidirectional ploughing will, in fact, move soil infinitely but, in practice, ploughing is carefully executed in a multidirectional manner in order not to move field areas more than the width of a furrow. Therefore artefact movement within the soil, while subject to a degree of spreading, an objective of this trial is to assess the amount of such spreading, is likely to remain within a relatively limited zone. Vertical movement of artefacts within the soil is also in need of analysis since a correlation between surface finds and the finds within the ploughzone has been conjectured (Reynolds 1987,Reynolds 1989) at circa 16%.

The development of this program, therefore, is a critical adjunct to this fundamental research enquiry. In its present state it responds extremely well to the data and allows considerable flexibility of analysis with statistical routines incorporated within its framework. Future development, with a significantly increased data base, should ideally include a future projection to simulate tens and hundreds of years or sequences of ploughing activity.

In its current form there is the possibility of using different presentations of the sequences already obtained to compare with excavated data to determine presence or absence of correlations. From the point of view of both the commissioner and end user, the program is proving particularly useful and efficacious. It has reduced the laborious hours of plotting out the sherd assemblages found in specific conditions greatly. Initially the scaling proved unusual but one quickly becomes used to the screen image. Because both the horizontal scales were disproportionately large in comparison with the vertical scale the ability to expand the last proved extremely valuable. The colour coding was specifically requested and responds as required.

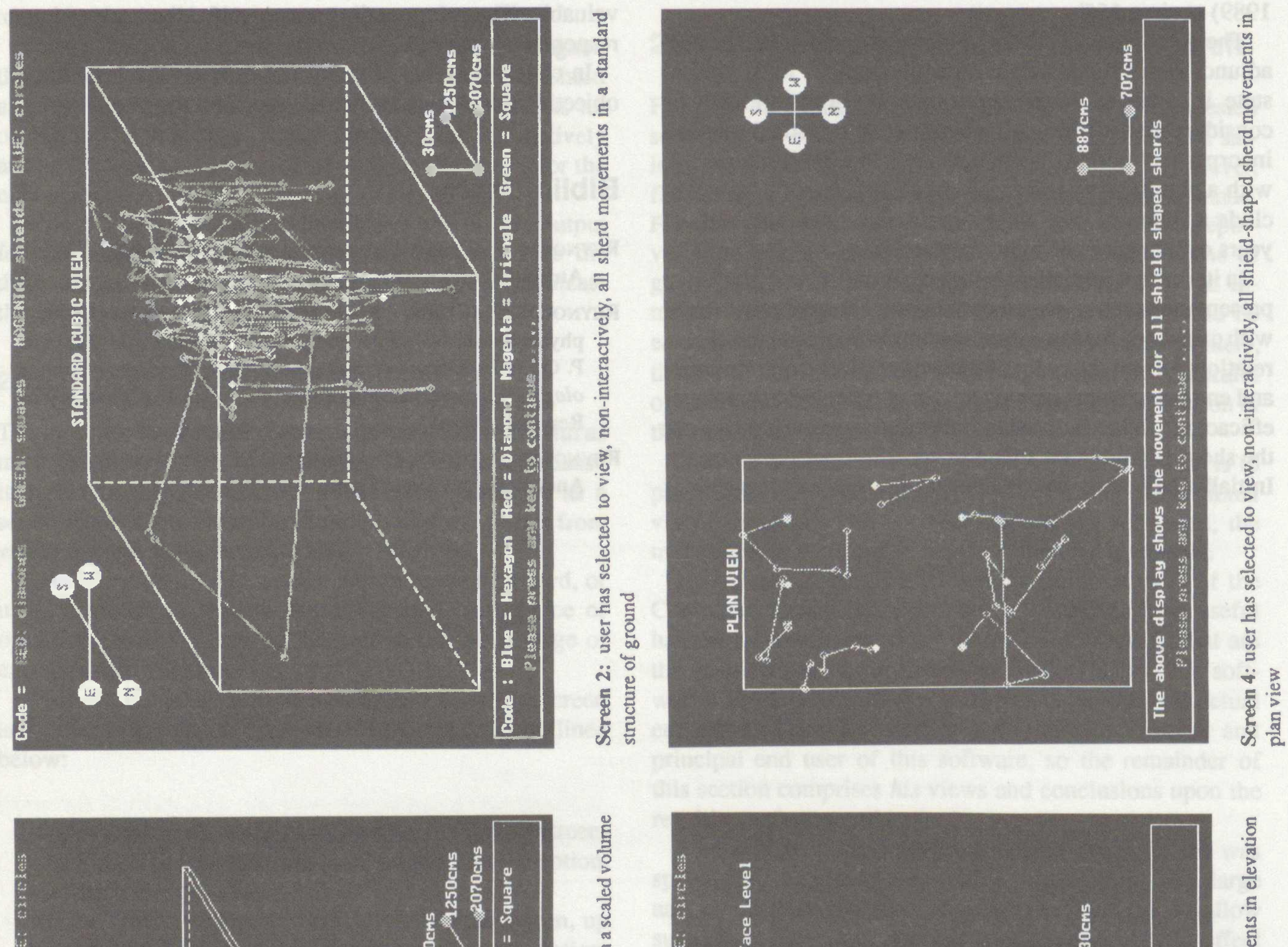
In conclusion this program not only achieves its initial objective but also offers further speculative options.

Bibliography

REYNOLDS, P. J. 1987. *Sherd movement in the ploughsoil.* Butser Ancient Farm Project Trust.

REYNOLDS, P. J. 1988. "Sherd movement in the ploughzone — physical data base into computer simulation", *in* Rahtz, S. P. Q., (ed.), *Computer and Quantitative Methods in Archaeology 1988*, International Series 446. British Archaeological Reports, Oxford.

REYNOLDS, P. J. 1989. *Sherd movement in the ploughsoil.* Butser Ancient Farm Project Trust.



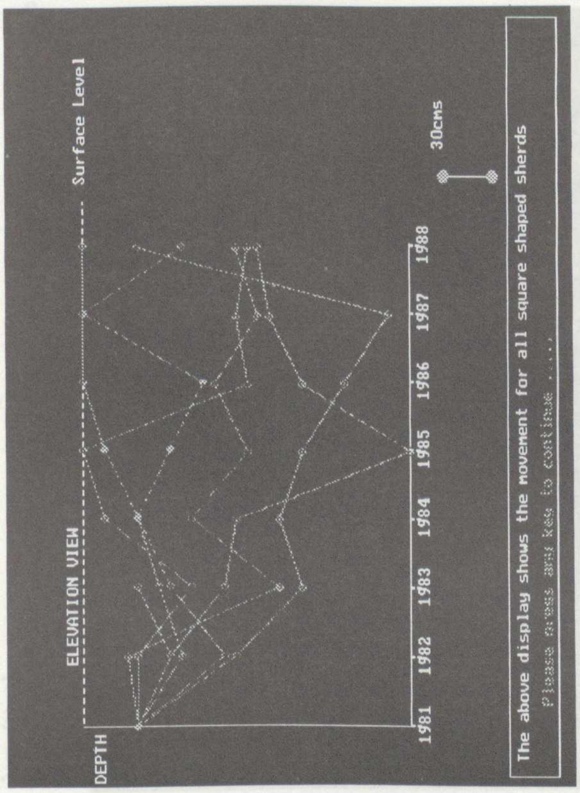
Screen 1: user has selected to view, non-interactively, all sherd movements in a scaled volume of ground

Screen 2: user has selected to view, non-interactively, all sherd movements in a standard structure of ground

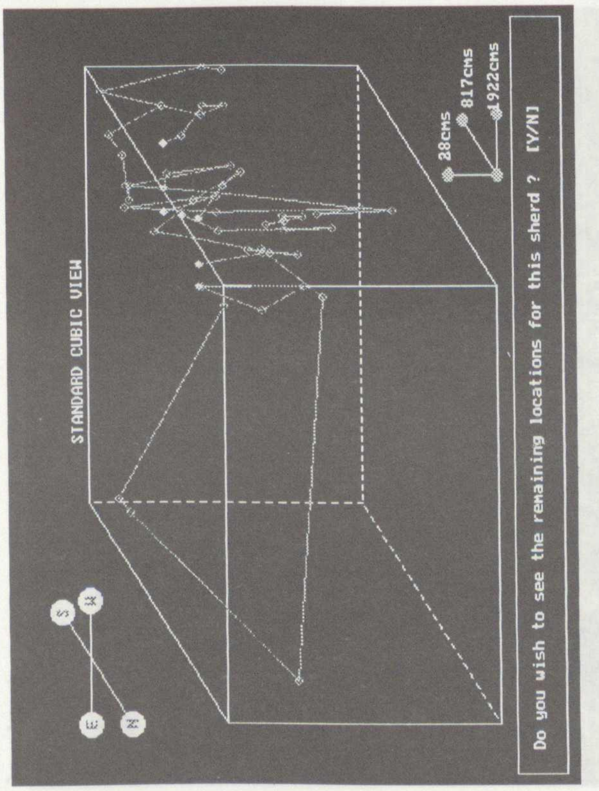
Screen 3: user has selected to view, interactively, a range of sherd movements in elevation view

Screen 4: user has selected to view non-interactively, all shield-shaped sherd movements in plan view

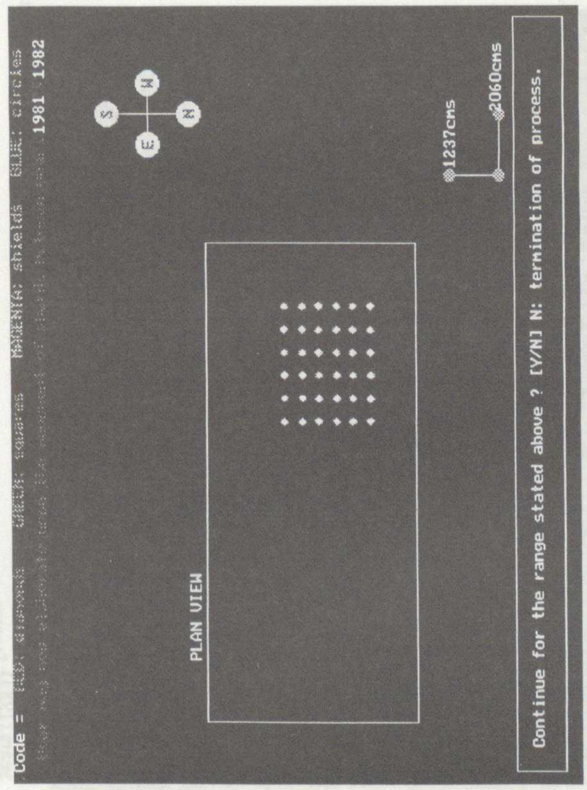
Figure 24.2: Screens 1–4



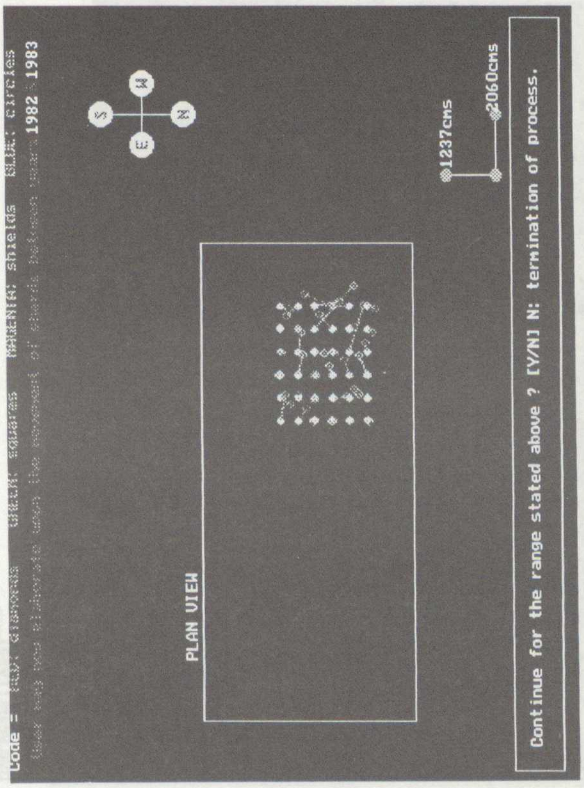
Screen 5: user has selected to view, non-interactively, all square-shaped sherd movements in elevation view



Screen 6: user has selected to view, interactively, specific circular-shaped sherd movements in standard structure

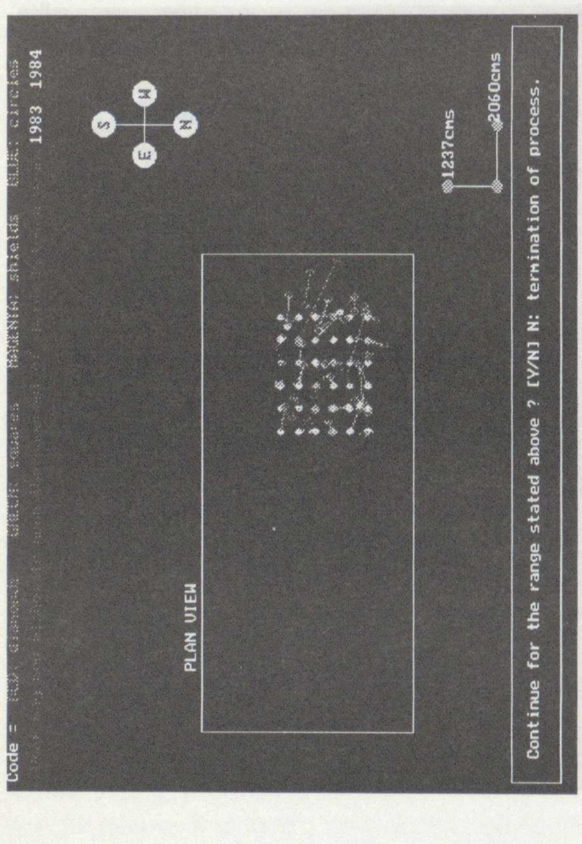


Screen 7: user has selected to view, interactively, all sherd movements in order of consecutive years (1981)

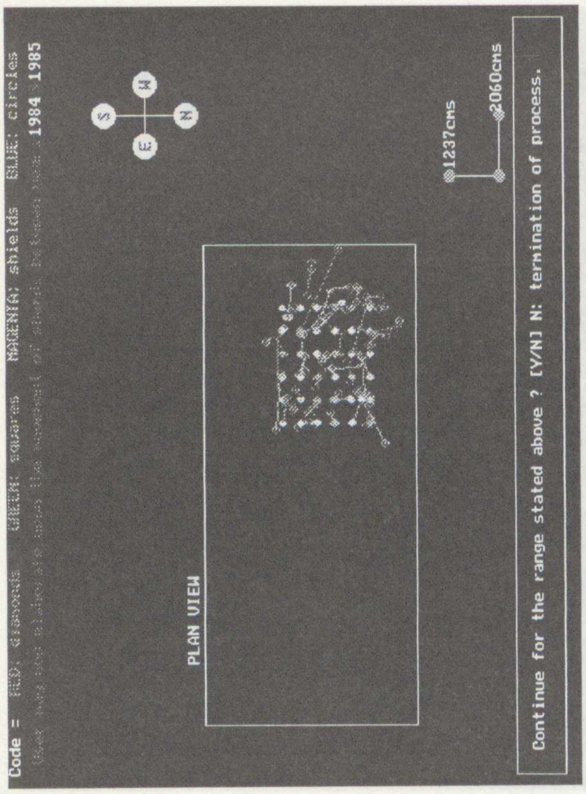


Screen 8: user has selected to view, interactively, all sherd movements order of consecutive years (1982)

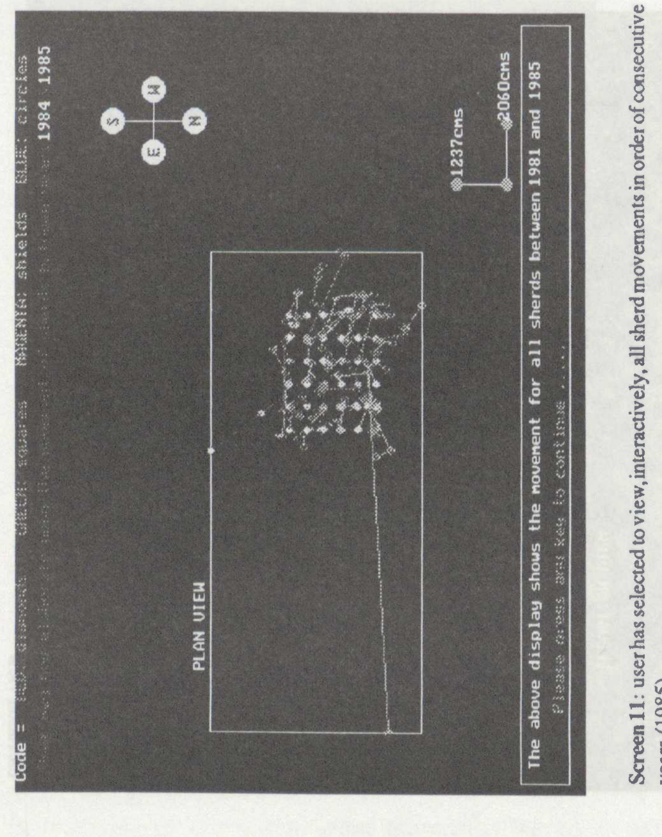
Figure 24.3: Screens 5–8



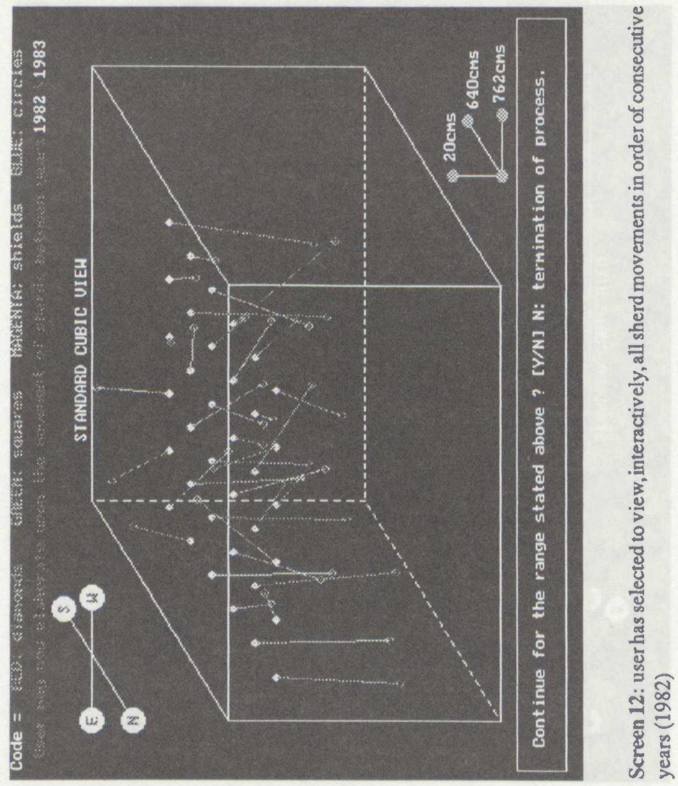
Screen 9: user has selected to view, interactively, all sherd movements in order of consecutive years (1983)



Screen 10: user has selected to view, interactively, all sherd movements in order of consecutive years (1984)

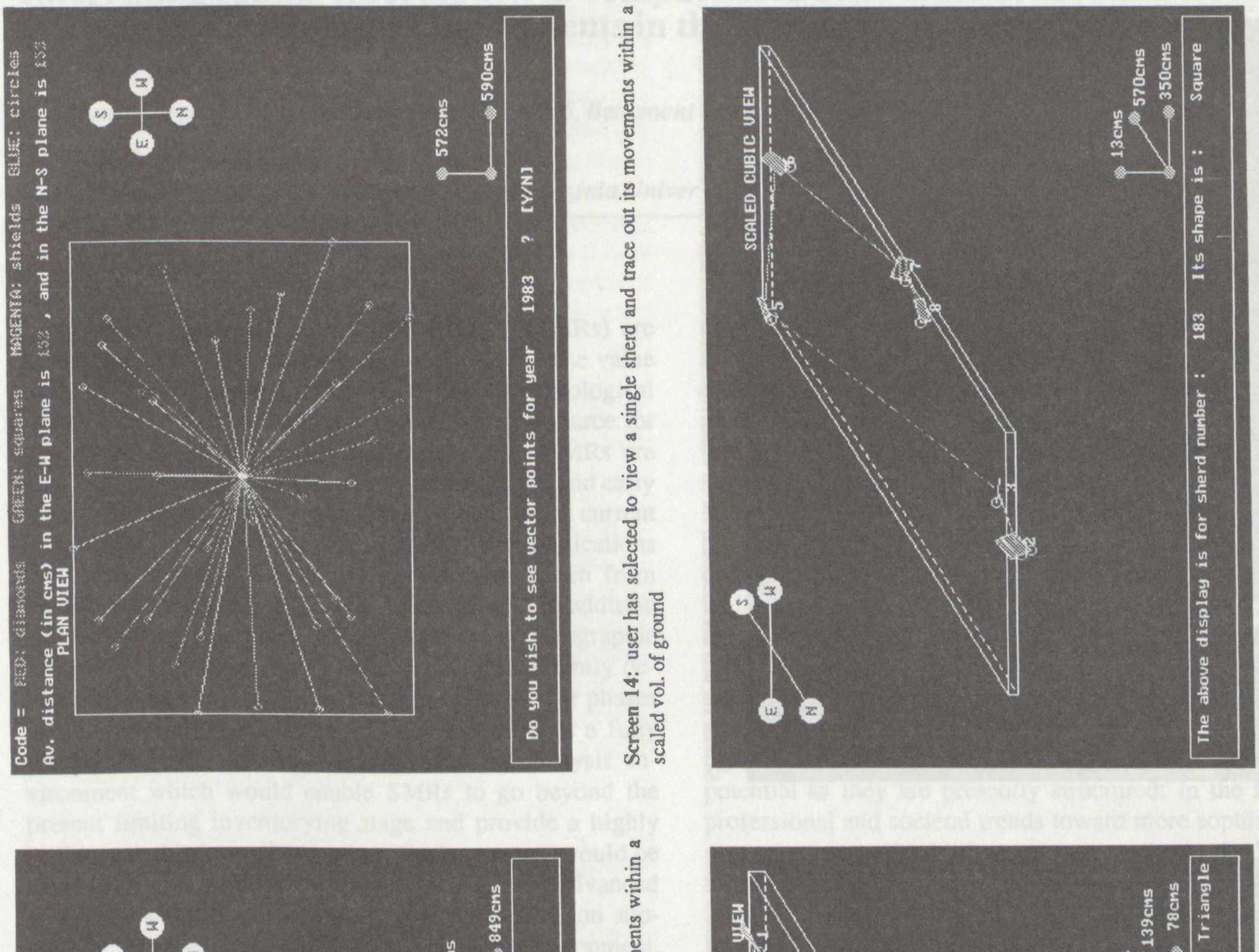


Screen 11: user has selected to view, interactively, all sherd movements in order of consecutive years (1985)



Screen 12: user has selected to view, interactively, all sherd movements in order of consecutive years (1982)

Figure 24.4: Screens 9–12



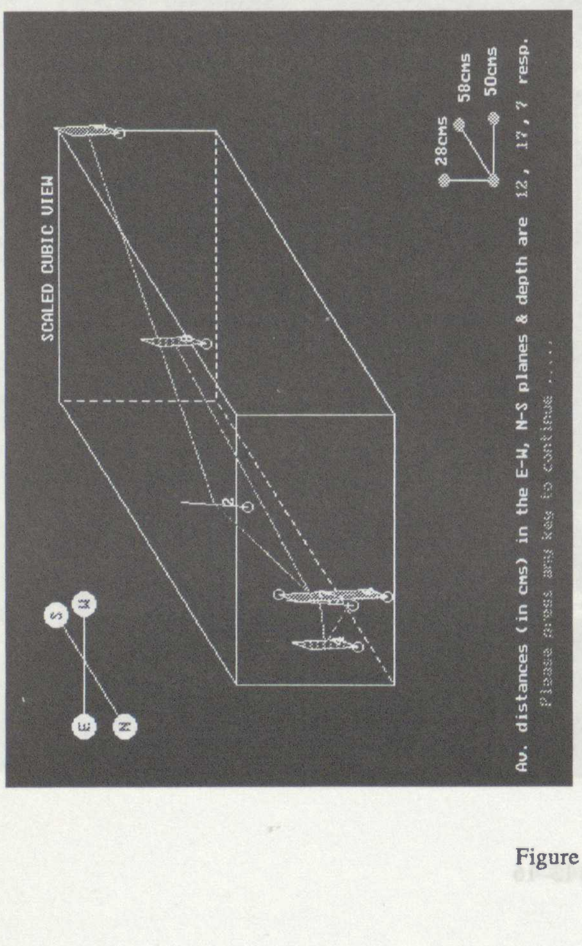
Screen 14: user has selected to view a single sherd and trace out its movements within a scaled vol. of ground

Screen 16: user has selected to view a single sherd requesting its ground surface frequency

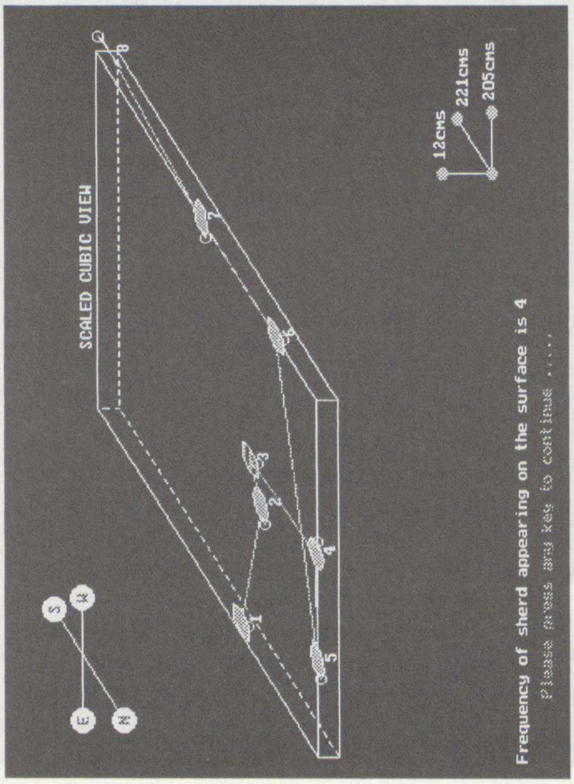
Screen 13: user has selected to view a single sherd and trace out its movements within a scaled vol. of ground

Screen 15: user has selected to view a single sherd requesting its average distances in each plane

Figure 24.5: Screens 13–16



Screen 17: user has selected to view a vector representation of sherd-movements non-interactively



Screen 18: user has selected to view a vector representation of sherd movements interactively

Figure 24.6: Screens 17–18