24

Some computer applications to petrological analysis of pottery

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24.1 Introduction

The success in comparing thin sections for the purpose of grouping and 'fingerprinting' types of material relies heavily on visual memory. In most cases, depending on the quantity of samples involved, it is possible to sort the slides roughly as analysis progresses, with a number of groups emerging at the end. However, when there are large numbers of slides involved, or the sample comprises individuals with very similar inclusions and subtle, but potentially significant, differences between them, it is far more difficult to group the material with confidence. However reliable the short-term memory may normally be, the image of each successive thin section examined inevitably succeeds in displacing those previously registered.

The recording of the analytical information varies, too. Few people use a recording form of any description, relying on free-text descriptions or rough notes. The final, communicable state of the information is normally in the form of free-text descriptions of varying formats and content. In most cases, relating published descriptions to the slides actually under investigation is unsatisfactory without a sample against which to make direct comparisons. Therefore, some standardisation in the format of data-presentation would be useful if it helps to relieve some of the ambiguities or gaps that occasionally occur in the type or quantity of information reported. Similarly, a stable (non free-text) method of data recording might encourage some uniformity in its final presentation.

A cumulative body of slides (such as occurs during large-scale, ongoing projects) may have many apparent groupings within which new samples have to be accommodated. The selection of an appropriate group can be tedious and time-consuming, particularly when there is no easily-accessible method of reducing the number of options (thin sections) against which visual comparisons must be made. Indeed, as work progresses the number and nature of the original groups themselves may change as new trends become apparent and others merge or lose their initial significance. It is also difficult to represent the precise differences between and within groups of slides in a convenient, graphic way. The plots (such as those derived from Principal Component Analyses or even simple scatter plots) so familiar from physico-chemical analyses are not normally found in conjunction with optical methods of examination because the data obtained are not normally expressed numerically (but see Schubert 1986 and the use of modal analysis with petrographic data).

The approaches discussed below may help with these problems.

24.2 Representation of thin section data by multidimensional scaling: initial trials.

The first problem, that of distinguishing groups of material within a potential population (of slides) arose from a suggestion of Dr. Morven Leese (British Museum Research Laboratory) who had been developing interface programs (with available packages) for use with data derived from subjective value assignments between pairs of objects. The application to thin sections was something that she had considered independently, but it also presented itself as an attractive possibility for ordering a large collection of *c.* 1000 Mayan pottery slides.

The geological monotony of the Maya Lowlands (chiefly sedimentary limestone) confers certain invariable attributes upon the data, and yet there are distinctions within this material that are apparent, if difficult to convey in free-text descriptions (*e.g.* Jones 1986, pp. 54–55). This may, and currently does, prove a communication problem.

A pilot scheme attempting to apply pairwise comparisons to thin sections of this sort was conducted on eight samples (from the Yucatecan Maya site of Komchen), with an extra, deliberately extreme sample acting as a control (from Ocos on the Gulf Coast). Although the control did not feature in the final calculations it helped provide a constant, neutral focus against which the other, visually similar samples could be compared. The seven Yucatecan samples were tempered with calcite and the Ocos sample with volcanic ash.

Each sample was compared against all the others using a scale of 1–5, with 5 representing the maximum similarity value. The test was conducted twice for each slide so that two similarity values were assigned for each comparison. These tests were conducted 'blind', by masking the identities of each sample so that factors of this sort did not influence the value assignments. In most cases the values were strikingly similar but where differences occurred the average value was calculated and used to create a matrix. The matrix represented a series of single distance measures, with the individual values representing the 'distance' between each pair of sections. The information was then run through a scaling program, 'MDSCAL' (Everitt & Dunn 1983).

It became apparent both during comparison and subsequently, after the scaling program had been run, that it was impossible to compare samples on a one-factor level. Thin-sections of pottery have many features that may be compared independently. For example, the details and optical behaviour of the clay matrix may vary between samples, particularly if the clays concerned are from different sources, or elutriated, or exposed to different firing conditions, whilst the more obvious inclusions, either native or added as temper, may appear too similar for any significant difference to be noted. However, although the nature of the inclusions may be the same from sample to sample, the size, state and quantities may be significantly different in some cases. Indeed, the subliminal influence of these factors on the original similarity tests revealed themselves in the stress factor that resulted when the results were compressed into two dimensions. The final configuration of eight points in two dimensions was *c.* 23%; this rather high value suggests that more than two distinct perceptual criteria were being employed. A three-dimensional configuration gives a far more acceptable stress factor of 1%. (Although this may be a reflection of the small number of samples involved, it is also commensurate with the unconscious use of three perceptual criteria.) The resultant plot of distances between the samples was rather difficult to interpret as no obvious groups emerged.

A further test using the same, pairwise comparison was conducted by Andrew Middleton (British Museum Research Laboratory) using a collection of Roman tiles as the test material. The tiles had already been grouped (into three related groups) by optical means. This, therefore, provided a valuable standard for comparison. (It was assumed, *a priori*, that these groupings were valid in the first place).

The two separate pairwise comparison tests revealed the following

1. The tests were time-consuming. A selection of around twenty samples (or twenty comparisons) takes about 30 minutes to perform; the time factor increases rapidly with the number of samples involved.

2. In both cases, the same samples analysed at different times produced different results. This method therefore allows for varying subjective criteria to be applied.

24.3 Numerical coding of attribute values: an alternative approach

A second approach was adopted with the tiles using Attribute Comparisons. This attempted to offset the obvious drawbacks of attempting an overall comparison between pairs of slides when potentially significant factors were not independently represented. The method entailed the coding of various attributes of significance and computing the inter-tile 'distance' values using a specially-written program. In this approach, the attributes are assigned values independently; they are not derived from comparison with any other sample. The codes chosen were the most basic possible, using values of 1–5 for each of the attributes identified. The attributes chosen were: the quantities of fine quartz, coarse quartz, mica and glauconite. The distance between any two tiles was calculated as being the sum of the absolute difference between corresponding coded values.

24.4 Comparison of pairwise comparisons and Attribute Codes results

In order to compare the two approaches of pairwise comparisons and Attribute Codes the respective matrices were both run through CLUSTAN (Wishart 1978) and MDSCAL.

The CLUSTAN option chosen used the hierarchical method of gradually combining clusters using Complete Linkage (or Furthest Neighbour) analysis. In this, the maximum distance between tiles in a cluster is the combination criterion; the least maximum difference between an individual item to be clustered and the items in each potential cluster determines new cluster membership, so that two very different samples do not appear in the same cluster. Complete Linkage was chosen as other methods, such as Single Linkage, Average Linkage and Ward's method when used with these data tended to create large clumps with stragglers, rather than smaller, distinct groupings.

The distance matrix used by CLUSTAN was run through MDSCAL in order to present a cluster plot—more useful as a method of data presentation than a dendrogram despite the inevitable distortion that this involves. The final plots derived from this method satisfactorily match the groups previously defined by optical means. Overall, the plots derived from the Attribute Code approach were more satisfactory than those derived from the pairwise comparison data (See Fig. 24.1). Effectively, the original, optically-defined groups were further divided by the programs used. More importantly, the original groupings were not seriously disrupted by these results.

Work is still in progress further to refine the quality of the results, such as by using non-hierarchical cluster methods (as hierarchical ones seem rather inflexible), and the use of more sophisticated distance measures.

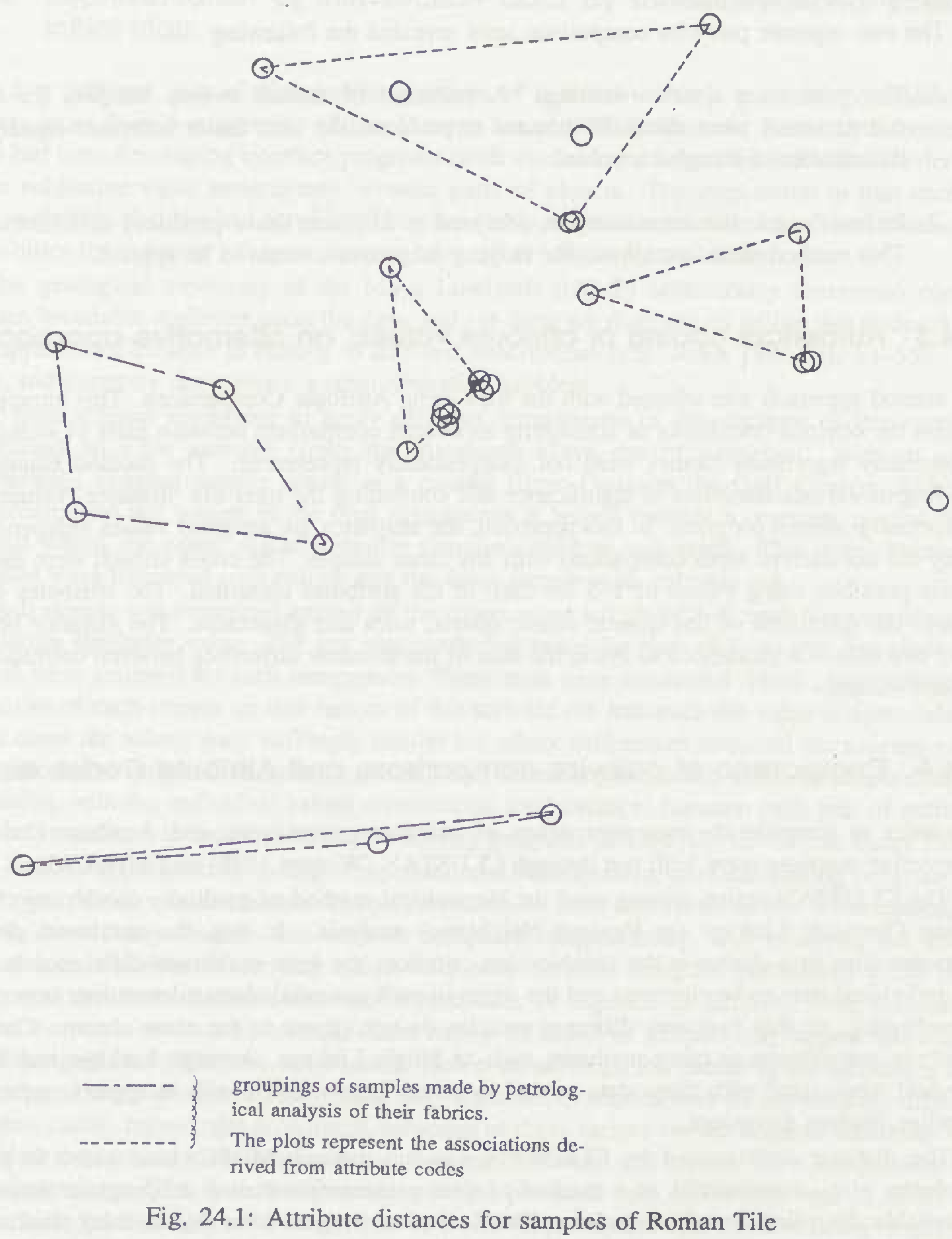

Fig. 24.1: Attribute distances for samples of Roman Tile

24.5 Conclusions regarding the initial trials

These initial investigations illustrated various points. The technique of Pairwise Comparisons is very time-consuming and, as such, is impractical for large numbers of slides. Similarly, the degree of distortion involved in placing the resultant values in two dimensions is unsatisfactory and is also dependent on the analyst not being influenced by the many factors which may independently be compared. A further complication is that, should a new slide have to be investigated, it would be necessary to compare this with all the others in the original sample. Attribute Codes provided a more practical and realistic reflection of the variables chosen for assessment. The information is free-standing and consequently, new samples can be assigned codes without the necessity to compare all the previous samples against them in order to create a new matrix. Not only is this a less time-consuming method but it provides a more suitable basis for the scaling programs used to order the information into a visual plot.

An interesting point in its own right is the use of subjective perceptions to acquire the raw data used in computerised analyses. Despite the apparent fluctuations within one person's value assessment it nevertheless seems possible to derive results from which plausible plots may be created. However, one area remains untested as yet—the comparison of the results of two independent analysts working with the same slides. It remains to be seen if two different plots might emerge as a result of differences in perceptual value assignments. On the other hand, it may be that only the scale attribute assessment might differ, rather than the overall groupings or relationships between samples. It would be most encouraging if this proved to be the case. However, it is likely that some form of standard will be required, should differences in scale become apparent (either between workers, or within one person's work over a period of time) in order that such differences may be minimised.

It would also be instructive to see the results obtained from a series of slides created from various places within a single vessel, and cut at different angles. This would mimic more exactly the real circumstances under which the samples are prepared. The ceramic technologist usually has to accept the samples offered, be they small fragments or complete sherds. It is often the body sherds which have no diagnostic value that are offered for analysis, and which may provide few clues as to their orientation within the original vessel. In particular, it is the platey, flat or blade-like minerals which may exhibit significantly different shapes and apparent densities depending on their orientation (e.g. the micas).

24.6 Database creation for petrological data

Julian Richards, in discussing the role of computers in archaeological theory and practice (Richards 1986, p.54) observes that the nature of archaeological research must inevitably change as a direct consequence of the involvement of information technology. He predicts that the increasing involvement of information retrieval methods in archaeology will inevitably impose a standardisation in the recording terms used. This is especially relevant to the accumulation of petrological data. Many samples are, effectively, unrepresented in the final reports that emerge from the analysis of a body of slides. More often than not a generalised, free-text, description is offered in which anomalies may be either forgotten, or presented as potential imports or other exotica, depending on the persuasions of the ceramicist/analyst (the influence exerted by decorative motifs or vessel morphology may manifest itself here). In order that genuine groupings and anomalies can be isolated as such, a very large number of samples needs to be analysed and the data stored independently. Each slide should be recorded and quantified as an individual; no sample should be forced into a group for convenience as it might be a member of another, unsuspected group.

In some respects, data derived from thin section analyses are ideal subject-matter for incorporation into a structured database. Not only is the information more satisfactorily stored in a uniform way, but it may be more effectively unified and defined by its grouping (as files) within the database. Clearly, though, the combination of elements comprising a database of this sort will inevitably vary according to the type of material the analyst is working with. A theoretical list of factors of potential use is included here (see below, Appendix), but there will be few occasions when all these criteria are either useful or can be accommodated as selection criteria in a search. The type of inclusions will similarly vary according to the sample involved and the actual organisation of the data within datafiles will also vary according to the factors surrounding the pottery itself. For example, it is unlikely that it would be necessary to sort and retrieve the pottery of say, Neolithic Britain and that of Moorish North Africa as part of the same process; in which case, it would not be necessary to store the respective details in the same database structure or file. It is more likely that the information from each data set would be stored according to other (temporal or geographical) criteria. In addition, the individual analyst, seeking to organise his own data with a microcomputer data-base package may find that the package imposes certain limitations on the number of fields that may be accommodated, or on the number of fields which may be sorted and selected for output.

Potentially there are two separate, but dependent, elements in the creation of a database for petrological data. The first concerns the storage of the ceramic data; the second, the effective analysis, interpretation and subsequent communication of the results derived from these data. Both the storage and analysis of the results can be encouraged by incorporating the kind of coded values used in the Attribute Code tests discussed earlier. At the simplest level, these codes can provide a discriminatory guide for further, visual comparisons between samples. They can also be used to guide the accommodation of a new sample within a pre-existing and defined group. In such cases, a typical member of each relevant group would provide the obvious standard for comparison. In attribute value terms, the standard is identified by summing the similarities between a typical sample and all others. The sample with the highest sum within a given set is the 'typical' member. This would be of especial use when dealing with very large data-sets (but note the comments of Main (this volume) in another context).

The potential also exists for this method to act as a precursor to the scaling and cluster techniques discussed earlier, as the groundwork for a matrix already exists. In any case the recording of the petrological data in a simple way, using codes where possible (*i.e.* minimising the free-text descriptions) would allow groups of pottery defined by a combination of chosen variable to be identified, refined and output for personal use or as a communication medium. The final assessment of the homogeneity of these groups would have to be based on an optical examination and possibly by the use of a scaling program to produce a two-dimensional plot and/or a clustering package. In either case, the number and identity of the relevant samples would be easier to define if the information were stored in this way.

24.7 Conclusions

Petrological data derived from optical methods of examination are not usually recorded or expressed in numerical terms. The identification of groupings within a body of slides is determined by the visual similarity of samples. The reliance on visual memory in the creation of such groups makes it difficult to retain and quantify the subtle differences that may exist between variables. The accommodation of further samples within the pre-defined groups is handicapped when there is no typical member of a group to act as a standard against which visual comparisons may be made.

The use of a subjective method of evaluating degrees of similarity between pairs of samples, and the assignment of Attribute Code values to selected variables proved useful as a means of numerically representing petrological data. The creation of a matrix with these values and the subsequent application of programs CLUSTAN and MDSCAL produced results that indicated the Attribute Code approach produced the most satisfactory plots of data. The (optically) pre-determined groupings within the slides were more accurately represented by Attribute Code matrices than by the pairwise comparison matrices. The approach was, in any case, far less time-consuming and practicable.

The standardisation in the recording of petrological data might be of use in ordering and communicating data that are difficult to express in free-text descriptions. The possibility of incorporating Attribute Codes as a feature within a database may help with the problems presented by large and increasing bodies of slides, where there are no obvious means of selecting significant members of a group to act as standards against which further comparisons or tests may be made.

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24.8 Appendix. Petrological data: some suggested elements for incorporation into a database

This appendix is aimed at the individual researcher; the assumption is made that database packages oriented towards the desk-top micro computers will be more generally used than relatively large and accommodating minicomputers or mainframes. This will therefore affect the individual's choice as to how the information may be arranged and stored. This is especially relevant to those fields which are necessarily related in some way *e.g.* inclusions type and size/frequency/state. Similarly, it may be necessary to store the ceramic typology and related details in a separate database, especially if it is strongly hierarchical. Few small packages will accommodate all potentially relevant information fields in one record format. In addition, the number of sorting and selection criteria is similarly limited.

Any of the main variables can be used as Attribute Codes. If Attribute Codes are nominated, it may be more appropriate to create a separate database for the information, with pointers (the record PRN/Key) to the other details on file elsewhere.

The choice of alphabetic or numerical codes (or a combination thereof) is also for the ceramicist to make. Again, the capabilities of the technology involved may influence this choice. A numerical code can generally be of more use, as relational Boolean operations may enable more realistic searching if subjectively-determined Attribute Code values form the basis for sorting and selection.

Identification

(Machine PRN) Assigned automatically
KEY:Lab. No. / Identification *e.g.* slide marking, sample number

Attribute Code Group *e.g.* ref. no. of typical member

Pottery Typology
  Main Group
  Sub-group
or Unknown

Sample origin: *e.g.* body sherd, rim, handle etc.

Physical attributes

1 Matrix

Macroscopic
  Colour
  Texture *e.g.* streaky, stranded, holey etc.
Microscopic:
  Appearance PPL—colour, texture
  Appearance XP: " "
  Birefringence: ( )
    Anisotropic
    Isotropic
    Undetermined (in case of overfiring, extreme reduction, overgrinding etc.)
Inclusions:
  e.g. quartz, mica, CaCO3

2 Inclusions: native or added as temper

Type: Broad *e.g.* Quartz, Mica, Feldspars, Pyroxene, Amphibole, Other
: Specific: *e.g.* biotite, hornblende, basalt

State: repeated for each inclusion type
  Rounded
  Sub-rounded
  Angular
  Sub-angular
Size: repeated for each element or type (actual size ranges may be varied according to material involved).
  Small < 0.01mm
  Medium < 0.5
  Large < 1mm and above
Quantity (number of individual grain occurrences; not absolute volume/area represented. The terms would have to be qualified).

    Rare
    Scattered/occasional
    Frequent
    Abundant

Dense

Distribution/Sorting: good, poor

3 Staining tests

Stain/method used e.g.
Carbonates and feldspars chiefly

4 Geological systems represented

Sedimentary
Metamorphic
Igneous

5 Notes (Free-Text) Key-Worded)

e.g. comments on sample preparation

friable material
over-grinding
minerals picked out during grinding etc.
i.e. anything of relevance not covered elsewhere

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