New Perspectives on Old Stones
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Analytical Approaches to Paleolithic Technologies
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Chapter 1
Analytical Approaches to Palaeolithic Technologies: An Introduction

Stephen J. Lycett and Parth R. Chauhan

Abstract We believe that it is instructive and timely to revisit themes that David L. Clarke (1968) raised in Analytical Archaeology. Here, we examine the extent to which they are being pursued by the contributors of this volume in the context of Palaeolithic studies. In highlighting certain “Clarkeian” trends, we discuss four themes: (1) hypothesis testing and formal analysis, (2) quantification and inferential statistical analysis, (3) models, (4) cultural transmission and lineages of artefactual traditions and (5) morphometrics.

Rationale Behind This Volume

As often noted, artefacts made from stone constitute the primary source of evidence regarding the behaviours and activities of fossil hominins and humans for the majority of prehistory. This volume grew out of a symposium (Analytical Approaches to Palaeolithic Technologies) held at the 2008 Society for American Archaeology meetings in Vancouver, Canada. The session had two primary aims. The first of these was to bring together as many people as possible who had demonstrated an interest in pursuing quantitative, hypothesis-driven, analytical approaches to the study of stone tools, particularly via novel techniques. The second aim was to draw attention to the fact that 2008 was the 40th anniversary year of David Clarke’s landmark volume Analytical Archaeology. We particularly felt that many of the principles, approaches and techniques highlighted at the symposium owed something of their origin to issues raised and discussed by Clarke, hence the title of our session. It may give readers of this volume greater insight to our motivations if they consider our original SAA abstract:

In the fortieth anniversary year of David Clarke’s instrumental volume Analytical Archaeology, the central theme of this session is the analysis of Palaeolithic technologies.
using a variety of quantitative and formal analytical procedures. The session will aim to incorporate a broad chronological and geographical range of Palaeolithic material from the Lower to Upper Palaeolithic. However, in all cases, participants will be encouraged to emphasise analysis of lithic material and novel approaches used therein, rather than its mere description or archaeological “philately”.

Given that a majority of participants from the symposium were able to contribute to the current volume, we hope that many of the original aims and sentiment of the session have successfully been carried over into the pages that follow. We are particularly pleased that the chapters cover a variety of different approaches (albeit with some dominant themes, as discussed below), and that material from both the Old and New Worlds is incorporated, which has ensured retention of a broad chronological coverage.

Rather than give a detailed “overview” of each chapter, what we hope to do in this introduction is highlight several apparent research themes that Clarke (1968) discussed in *Analytical Archaeology* (and elsewhere). We hasten to add that this should not be taken to mean that the current volume is intentionally a “tribute” volume to Clarke, much less a deliberate festschrift. It is also not even to be taken to mean that all of the contributors necessarily subscribe to all aspects of Clarke’s views, nor even necessarily consider him a direct influence. Rather, given that four decades have now passed since the publication of his landmark volume, we believe that from an editorial viewpoint it is instructive and timely to revisit themes that Clarke raised, and to examine the extent to which they are being pursued by the contributors of this volume. It is, of course, also important to note at the outset that Clarke’s book was not exclusively orientated toward the study of stones tools, but was aimed at instigating a much broader agenda for prehistory and archaeology in general. It must also be remembered that Clarke’s own views were part of a wider set of changes going on within (the “New”) archaeology at the time, and concurrent with the writings of some equally influential figures, perhaps most notably, Lewis Binford (for historical overviews see e.g. Trigger 1989; Shennan 1989, 2004; O’Brien et al. 2005). However, as we hope to demonstrate in the following sections, several particular themes that Clarke advocated as providing avenues for a rigorous interrogation of prehistoric evidence, appear to be alive and well in some current research being pursued in the field of lithic studies. Indeed as we aim to show, such themes, if anything, appear to have seen something of a resurgence within the last few years.

**Exploring the Legacy of David Clarke in the Contemporary Analysis of Palaeolithic Data**

In highlighting certain “Clarkeian” trends, we note five particular themes, all of which are elaborated upon below in relation to the contributions in this volume as explicit examples: (1) hypothesis testing and formal analysis, (2) quantification and inferential statistical analysis, (3) models, (4) cultural transmission and lineages of artefactual traditions and (5) morphometrics.
Hypothesis Testing and Formal Analysis

Hypotheses are developed to relate observed properties to one another by means of a structural concept. In this way an hypothesis, or an hypothetical model, is constructed for the sake of predicting certain correlated regularities.

D.L. Clarke (1968: 643)

In a letter to a colleague discussing the practice of scientific endeavour, Charles Darwin once remarked: “How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service!”¹ He also remarked in the same letter that in the absence of such a standpoint, one “might as well go into a gravel-pit and count the pebbles and describe the colours”. Sadly, in our own field, we have probably all seen examples of lithic studies that appear little more than pebble counting.

As much as any particular “technique”, the word analytical in the title of Clarke’s (1968) treatise refers to the more general philosophical principle of using formal empirical observations in the building and testing of hypotheses. “Formal” in this instance refers to the use of quantitative data (be it categorical, ordinal or metric), to assess in a detailed manner the relationship (or otherwise) between a set of empirical phenomena and a particular model or hypothesis derived from theory or observation, the assumptions and predictions of which are made explicit. Such an approach can be contrasted with those of description and narrative.

As discussed by Hill (1972) in Clarke’s (1972) Models in Archaeology, in this sense the word “analysis” takes on a quite different and particular meaning from the way it is all too commonly applied (Hill 1972: 86), structuring everything from question posing, hypotheses, predictions (i.e. the test implications of hypotheses) to data collection, to result “interpretation”. Wryly, Hill (1972: 88) suggests that there is an advantage to structuring research design according to a sequence of “problem” → “hypothesis” → “data”, rather than the inverse of “data” → “hypothesis” → “problem”!

We hasten to point out that we ourselves do not see strict hypothesis testing as the only means to viable analysis. Indeed, the authors in this volume differ in the extent to which their analyses are framed in a strict hypothesis testing framework: all, however, assess in a formal manner relationships between a set of empirical phenomena and a particular model or hypothesis derived from theory. Indeed, even Hill (1972: 62) pointed out that a strict distinction between inductive and deductive reasoning is somewhat false because both will be used at various points in an ongoing research programme. Rather, what we would suggest is that formal hypothesis testing should become more regularly used once again in Palaeolithic enquiry. It appears to have been out of vogue for a majority of workers, meaning that an important tactic in the lithic analyst’s tool kit has been under-utilized, if not, under-taught. Several contributors in this volume, however, delineate hypotheses and explicitly test their predictions.

Some of the clearest examples can be seen in the chapters by Buchanan and Collard, Clarkson, and Monnier and McNulty (see also, Costa).

Buchanan and Collard test two hypotheses concerning traditionally recognised “shape-types” in Palaeoindian projectile points. The first hypothesis concerns the notion that blade shape effectively discriminates between projectile points from different traditionally held types. Hence, the prediction underlying this hypothesis is that shape information classifies points to “type” with high degrees of efficacy. They tested this prediction with a multivariate classification procedure [discriminant function analysis (DFA)]. Results of this first analysis were mixed: blade shape was able to provide a reliable basis for discrimination in some cases, less so in others. In their second analysis, Buchanan and Collard tested a hypothesis originally put forward by Flenniken and Raymond (1986), which proposed that resharpening of projectile points is likely to reduce the ability for discrimination between traditionally held Palaeoindian “types” due to sharpening-induced convergence in shape. Hence, the prediction in this analysis is that smaller points should have greater misclassification rates than larger points. This prediction was not supported in Buchanan and Collard’s results, thus undermining the basic premise upon which the resharpening/convergence hypothesis is based.

Raw material has also long been thought of as a major, if not dominant, influence on the form of stone artefacts (e.g. Goodman 1944) such that it might outweigh the influence of cultural tradition. In his chapter, Clarkson also uses the classification technique of DFA to test the hypothesis that raw material is of greater influence than factors such as cultural tradition in discriminating between cores from the Howiesons Poort MSA of southern Africa. Using the DFA multivariate statistical procedure, Clarkson tests the extent to which different cores are correctly assigned both to raw material type and to geographic region. He finds that cores are correctly classified by raw material type in only 46% of cases, while cores are correctly classified to region in 72.8% of cases. Hence, Clarkson correctly cautions that both raw material and regional traditions appear to be influencing core shape, but also notes that “raw material differences would appear to be subordinated to other causes of variation in creating differences between regions”. Clarkson’s analysis shows that even within a hypothesis testing framework, the relative influence of alternative – but not necessarily mutually exclusive – influences on stone tool form can be evaluated objectively and formally.

Monnier and McNulty test a hypothesis concerning the thorny topic of “behavioural modernity”, especially as it relates to cognitive evolution. As these authors note, it has for some time been contended that standardization of lithic artefacts is an indicator of behavioural modernity. Monnier and McNulty test the extreme prediction of this “standardization hypothesis”; that is, that artefacts made by anatomically modern humans (AMHs) are always more standardised than those of non-moderns (i.e. Neanderthals). Using geometric morphometric techniques they show that Neolithic artefacts are not always more standardised than those of Neanderthals. As the authors note, this rejection of the strict prediction of the “standardization hypothesis” does not rule out a “softer” version of the hypothesis suggesting that AMHs had a greater capacity to standardize. However, it does show that standardization itself is a variable that is independent of, and not necessarily
directly reflective of, cognition or “modernity”. Rather, alternative explanations for standardization in artefacts (e.g. function, raw material, tradition) should be explored as causes of standardization, at least on an equal basis. Monnier and McNulty’s analysis is illustrative of one of the epistemological strengths of the hypothesis testing approach in terms of transparency regarding what a set of data does – and equally important – does not tell us about a specific issue, and in so doing allows robust and clear assessment of the value of results in moving both knowledge and debate forward.

Model building and the assessment of goodness-of-fit between empirical data and a model’s parameters can be seen as a specific form of hypothesis testing (Clarke 1972), which is also used by several contributors here (e.g. Brantingham, Braun, Grove, Lycett, Shott). However, given the particularly prominent position that the use of models took in Clarke’s overall philosophy, we discuss this in a separate section below.

The use of experimental archaeology can also be seen as a specific form of hypothesis testing (Clarke 1972: 54), which has great applicability in the case of functional items such as stone tools (Hiscock and Clarkson 2005; Shott et al. 2000; Shea et al. 2001; Patten 2005). We detect something of a recent reinvigoration and diversification in the use of quantitative experimental procedures for the analysis of lithic technologies. Recent examples of this include Machin et al.’s (2007) quantification of biface form and their assessment of variation in specific morphological parameters and efficiency in terms of butchery speed. Other examples include Sisk and Shea’s (2009) study of Levallois point performance during trials as projectile points, and also Eren et al.’s (2008) assessment of the productivity in blade cores versus discoid cores. Toth et al.’s (2006) quantitative comparative analysis of experimental flakes produced by humans and Kanzi the bonobo (Pan paniscus) chimpanzee – directly alongside the earliest Oldowan examples from Gona, Ethiopia – provides a further example. Equally exciting, is the experimental work of Stout and colleagues which uses brain imaging technology to study brain function during the replication of prehistoric stone tools (Stout 2006; Stout et al. 2000, 2006; Stout and Chaminade 2007). In this volume, Clarkson uses experimentally knapped cores in order to assess the utility of a novel method for quantitatively describing core morphology, prior to moving on to an archaeological case study. Likewise, Braun and colleagues test their 3D method for calculating flake platform surface area (and subsequent determination of flake size) against a series of experimental pieces made on the same raw material as Oldowan artefacts from the Okote Member of the Koobi Fora Formation, northern Kenya.

Quantification and Inferential Statistical Analysis

*Counting and measuring reduce vagueness, increase specificity, upgrade standards of arguments, allow error estimates, numerical manipulation and explicit testing of hypotheses*

D.L. Clarke (1972: 55, emphasis in original)
In the above quoted sentence, David Clarke succinctly summarizes the major merits of quantitative, and particularly statistical, approaches over alternative forms of argumentation: repeatability, precision, robusticity and testability. Statistics are, of course, not infallible – they are statements of probability, not of fact. However, even this fallibility is a strength since the recognition, and more importantly, correction of any such error is facilitated – via transparency of operation – and in turn assists our ability to improve upon and extend previous studies via further empirical work. In so doing, research results have a greater potential to become progressively cumulative, thus helping to avoid the downward spiral of knowledge that results from argumentation of the “if, but, maybe” variety (see Clarke 1972: 43 for an interesting discussion on the growth of archaeological knowledge from this perspective).

In this volume, Grove highlights the wry observation of Hammond (1979: 7) who noted that due to David Clarke’s advocacy of quantification in archaeological analysis his books “were usually ignored by the most traditional-minded of British archaeologists”. Fortunately, however, archaeology has seen an increased use of quantitative and statistical methods over recent decades, which is of course at least partly driven by the now commonplace presence of powerful desktop computers and increased availability of more user-friendly software. Indeed, arguably, lithic studies have seen a greater use of quantitative data than even some other areas of archaeology. This is because lithic artefacts lend themselves to being counted and measured, and are often the only piece of archaeological evidence actually recovered from a prehistoric “site”. It is unsurprising, therefore, that even introductory textbooks on lithic studies involve discussions on using quantitative data (see e.g. Andrefsky 1998; Kooyman 2000).

Despite this apparent widespread use of quantitative data in our field, however, it might still be doubted whether the use of statistical methods – particularly inferential statistics – are a prominent mode of practice in lithic studies. Rather, it might be argued that the most frequent use of quantitative data in lithic studies consists of little more than a table of range values for a set of given variables (i.e. maximum and minimum values), their mean, and if we are lucky, a standard deviation. Darwin might have referred to this practice as fancy pebble counting. Such a practice is usually followed by an “interpretation” or theory of what such data may or may not mean. In other words, only a subset of lithic studies take the extra step of utilising this hard-won data more formally, within an explicitly hypothesis testing or model-fitting framework, via the use of inferential statistics.

Reasons for this are potentially mixed. It is understandable, for instance, that lithic studies, as in archaeology in general, draws people who are more thrilled by

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2 Inferential statistics is the branch of statistical analysis that allows determination of statistical significance, whereby differences or patterns in datasets can deemed meaningful according to quantifiable probability. Hence, inferences may be drawn about a set of data within the bounds of statistical confidence limits. Inferential statistics are in this sense distinguishable from descriptive statistics, which merely describe data in different ways (i.e. counts, range values, averages, standard deviations, etc.) (see Shennan 1997 for further discussion).
the thought of holding an artefact made millennia ago than they are by the thought of sitting down with a manual describing, for example, Discriminant Function Analysis. This, at least for some students, may be compounded by a lack of formal training. Indeed, despite the commonplace presence of computers, it might prove an informative exercise to determine whether the average archaeology undergraduate spends as much time as an average biology undergraduate being trained in statistical methods, despite the importance of quantitative data in both fields. Such a situation leads to an impasse more problematic than simply a failure to utilize an important set of research tools or even simply a passive tendency to ignore results from studies that use statistical approaches: it leads to ignorance, and ignorance breeds active resentment or what Shennan (1997: 1) has referred to as “rejection on the basis of uninformed prejudice”. Correction of such prejudice can be achieved by enthusiastic instructors, but scholars interested in pursuing these techniques may also have to take matters into their own hands and make the efforts required to learn these techniques (and their underlying principles) for themselves. Fortunately, given the increased number of user-friendly statistical manuals and software packages appearing in recent years, this is now arguably a more achievable task than ever before.

Presumably, David Clarke would have been pleased to observe that all the contributors to the current volume use statistical methods of one sort or another. He would presumably also have been pleased to see the breadth of statistical

<table>
<thead>
<tr>
<th>Statistical procedure</th>
<th>Chapter(s)</th>
<th>Category of technique</th>
<th>Further reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boxplots/Box-and-whisker plots</td>
<td>Brantingham, Braun et al., Clarkson</td>
<td>Descriptive</td>
<td>Shennan (1997)</td>
</tr>
<tr>
<td>Kruskal Wallis</td>
<td>Monnier and McNulty</td>
<td>Inferential</td>
<td>Quinn and Keough (2002)</td>
</tr>
<tr>
<td>Mann Whitney U test</td>
<td>Chauhan</td>
<td>Inferential</td>
<td>Shennan (1997)</td>
</tr>
<tr>
<td>MANOVA (Multivariate Analysis of Variance)</td>
<td>Buchanan and Collard, Costa</td>
<td>Inferential</td>
<td>Hair et al. (1998) and Quinn and Keough (2002)</td>
</tr>
<tr>
<td>Regression</td>
<td>Braun et al., Lycett</td>
<td>Inferential</td>
<td>Shennan (1997) and Quinn and Keough (2002)</td>
</tr>
<tr>
<td>Cluster analysis</td>
<td>Chauhan</td>
<td>Multivariate</td>
<td>Shennan (1997) and Hair et al. (1998)</td>
</tr>
<tr>
<td>PCA (Principal Components Analysis)</td>
<td>Costa, Iovița</td>
<td>Multivariate</td>
<td>Shennan (1997) and Hair et al. (1998)</td>
</tr>
<tr>
<td>CVA (Canonical Variates Analysis)</td>
<td>Costa</td>
<td>Multivariate</td>
<td>Hair et al. (1998)</td>
</tr>
<tr>
<td>DFA (Discriminant Function Analysis)</td>
<td>Buchanan and Collard, Clarkson</td>
<td>Multivariate</td>
<td>Hair et al. (1998)</td>
</tr>
</tbody>
</table>

Note that specialist model-fitting and morphometric procedures used by some contributors are not listed
techniques deployed. Table 1.1 describes the main statistical procedures used by the chapter authors at various stages of their analyses. The methods listed include combinations of descriptive procedures (e.g. box-and-whisker plots) multivariate procedures (e.g. DFA, PCA), as well as inferential statistics (e.g. MANOVA, regression). As will be noted, some chapters contain nested combinations of several statistical procedures. In the interests of assisting the inquisitive reader who may wish to learn something more about these techniques (see point mentioned in the previous paragraph), the table also provides references to sources that describe the techniques in more detail. It should, of course, be remembered that even Table 1.1 comprises only a small subset of the procedures that may be of utility to lithic specialists, and the literature listed will also give fuller accounts of some of these additional methods. It should also be noted that the statistical methods listed in Table 1.1 are in addition to some of the more specialised procedures associated with the quantitative model-fitting techniques used by some contributors (e.g. Brantingham, Braun et al., Grove, Shott) and the specialised morphometric techniques used in some chapters (e.g. Braun et al., Clarkson, Costa, Lycett, Iovita, Monnier and McNulty), although useful references may be found in the relevant chapters pertinent to these techniques, in addition to the descriptions provided by the authors themselves.

**Models**

As noted earlier, the application of formal models might be seen as a particular category of hypothesis testing. Models, of course, occupied a prominent position in the overall philosophy of Clarke (1968, 1972) who recognised their pivotal role in structuring and sharpening a set of theoretical expectations to the point that archaeological data could be employed in a more robust role than one of polemical narrative. As Clarke (1972: 1) put it “[m]odels are pieces of machinery that relate observations to theoretical ideas”. There are, however, several distinct categories of model (“machine”) that are of use to archaeologists, including lithic analysts (Clarke 1972; Gibbon 1984).

Clarke (1972: 10–42) noted that the most useful forms of model for the archaeologist can be classed under the general term of “Operational Models”. Such models come in a variety of guises but all act as a theoretical apparatus for deriving a set of predicted parameters based on explicit logic, which can then be measured for goodness-of-fit against empirical data. Their emphasis is, therefore, on predicting the empirical outcomes of a specified operational process, whereby in instances of high goodness-of-fit, that process can then reasonably be assumed to have been in operation thus potentially explaining why parameters in the archaeological record take the form they do. Under this general definition of “Operational Model”, three sub-categories of model can be discerned: mathematical models, analogue models
Analytical Approaches to Palaeolithic Technologies: An Introduction

and null models. It should be noted that these three categories of model are not necessarily mutually exclusive and sometimes overlap in certain properties.

Mathematical models: This form of model is based purely on logic (i.e. no empirical information is necessary a priori for their construction). They consist of “functions” written in calculus where numbers or symbols represent defined properties [which is why they are sometimes referred to as symbolic models or iconic models (e.g. Clarke 1972; Gibbon 1984)]. They express the relationship between specific properties in precise mathematical terms. Sometimes such models also form the basis of simulation, which are increasingly popular in archaeology with the greater ease of access to powerful computers (e.g. Shennan 2001; Henrich 2004; Lipo et al. 1997; Brantingham, this volume).

Gibbon (1984: 112) provides a somewhat crude but illustrative description of how a mathematical model potentially operates in archaeological settings, which can be modified to a hypothetical lithic example. In Fig. 1.1a, X represents weight of a stone hammer used during flake removal from a core, and Y represents the average length of flake scars produced during this operation. Under such circumstances, X is the independent variable, Y is the dependent variable, and b is the function (linear coefficient) that allows calculation of Y when given a value for X. The model can thus be expressed as Y = bX. In Fig. 1.1b, the model is extended by adding an additional independent variable (Z) which represents the use of a second hammer stone of a different weight than given for X. The new multivariate formula for the dependent variable Y thus becomes Y = b_1X + b_2Z.

Examples of the use of mathematical models of this nature in the current volume can be seen in the chapter by Brantingham on core reduction. In his contribution, Brantingham uses three models representing independent decisions during the reduction of cores, which take their names from their mathematical properties: These are the Bernoulli model, the Markov model and the Price model. Brantingham tests the goodness-of-fit between the parameters of each model against an archaeological data set for which the assumptions of the particular model might a priori reasonably be expected to hold true. The Bernoulli model is evaluated with a series

![Fig. 1.1](image)

Fig. 1.1 (a, b) Hypothetical example of a simple mathematical model (Modified after Gibbon 1984: 112)
of Oldowan cores from Olduvai Gorge (Tanzania), and the Markov and Price models are compared against an assemblage of Upper Palaeolithic Levallois blade cores from Shuidonggou (northwest China). In determining where the models’ parameters fit and do not fit the empirical data, Brantingham is able to demonstrate tactical decisions on the part of the knapper. For instance, a key prediction of the Bernoulli model is that poor quality raw material will be more intensively reduced. However, in the case of the Oldowan cores from Olduvai Gorge, Brantingham demonstrates that a directly contradictory pattern is present whereby higher quality raw materials are more intensively reduced. Such analyses are representative of some of the fundamental protocol of utilizing mathematical models (and indeed models in general) in terms of making a series of simplifying – but precise and explicit – assumptions, such that parameter values taken from empirical data can be compared for goodness-of-fit against those precisely laid out assumptions.

Further examples of mathematical modelling can be seen in the chapter by Grove, who provides functions for hypothesised hunter-gatherer movements between sites (e.g. the Lévy Walk). This “random walk” model has been shown to adequately characterise the movements of some non-human animals, and Brown et al. (2007) have suggested that it accurately depicts foraging patterns of the Dobe area !Kung of Botswana. Here Grove re-applies the model to data from the !Kung and compares it alongside an additional (lognormal) model. Grove finds that the Lévy Walk model effectively characterizes some aspects of movement in these hunter-gatherers, but not all. In particular, the very large numbers of small distances predicted by the Lévy model do not occur. Indeed, he finds that the lognormal model provides a better fit to the data in this regard. He uses this observation to further hypothesise on the nature of movement strategies in the !Kung and hunter-gathers in general, shedding further light on some older ideas discussed by Binford (1982).

**Analogue models:** In contrast to the pure rule-based logic of mathematical models, analogue models explicitly use information from better known or empirically documented situations (e.g. experiment or ethnography) to generate predictions. It is this sense of analogy between one set of empirical phenomena and another from which this subset of models takes its name.

In general, the line between many testable hypotheses (see above) and analogue models will be very fine if not somewhat false. However, a useful distinction is to consider analogue models as heuristic instruments that go further than a hypothesis and use some constructed device – either a diagram, set of numerical figures (e.g. independent data matrix) and/or explicit logical sequence – to help formulate predictions. Construction of such a device may itself involve some analytical component (e.g. cluster analysis of ecological, geographical or temporal parameters) or combine a priori empirical knowledge and logic – the theoretical and empirical underpinnings of which should, of course, be made explicit. Analogue models will be most powerful when predictions derived from them can be tested using inferential statistical procedures (i.e. goodness-of-fit can be assessed as statistically significant or non-significant at $p \leq 0.05$).

In this volume, Shott provides a demonstration of analogue model use. Shott compares reduction/curation distributions of Palaeoindian bifaces against quantitative and graphic models (survivorship curves) more typically applied in the study of population demography. Hence, these analyses aptly illustrate the principle of
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taking empirical knowledge about how phenomena react in one sphere and applying it another to help provide an understanding of data patterning. Braun and colleagues also take advantage of such models in their analysis of oldowan material from koobi fora (kenya), which draws attention to the fact that models of this nature may be of utility in a wide variety of geographical and chronological settings.

lycett also utilises several examples of analogue model. in one of his analyses, an analogue model is used to determine whether patterns produced via a cladistic analysis of acheulean handaxes may be reflecting raw material factors rather than phylogenetic patterns influenced by social transmission processes. he builds a “model tree” based on the raw material of the assemblages concerned and compares the shapes of this tree statistically against those produced during the cladistic analysis. the logic being used here is that if the cladistic patterns are not significantly different from those based purely on raw material, then it may be taken that raw material is having a dominant influence on the “phylogenetic” patterns produced. conversely, if the raw material model tree is statistically different from the cladogram, then raw material factors may be confidently rejected as a dominant cause of the patterns displayed.

null models: null models comprise the simplest (i.e. most parsimonious) explanations for a given data pattern. the strength of this form of model lies in the fact that if not rejected, the model adequately explains the data and more complex scenarios (however intuitively appealing) cannot be given intellectual priority.

stochastic (i.e. random or “neutral”) models are a specific type of null model, and arguably the most well known (although it should be emphasised that not all null models invoke stochasticity as the means of appealing to parsimony). stochastic models are truly “null” in the sense that they take randomness as the default position: only when a deviation from randomness is found is there any need to begin seeking alternative explanations for the observed “pattern”. some of these models may be expressed as mathematical functions, such as the lévy walk model used by grove discussed above.

in recent years, null models have become more common in studies of lithic data. for instance, brantingham (2003) has shown that raw material selectivity can be modelled in a “neutral” or random sense. hence, if the use of raw material in a given region conforms to the patterns of the neutral model there is no need to invoke tactical decision-making processes concerning raw material use. if, however, the pattern of raw material use does not conform to the parameters of the neutral model, tactical raw material usage may confidently be invoked. in the current volume, braun also draws on such logic in his analysis of material from koobi fora.

in sum, models are formed *a priori* for a specific purpose. as with the word “analytical”, the term “model” has frequently been misused, especially as a synonym for a “theory” that is usually derived (post-hoc) from a narrativical discussion of a set of “data”. as should be apparent from the foregoing, a formal analytical model must be far more than this and is employed tactically in a very different manner. that is, they form a structured link between a set of theoretical parameters and predicted empirical patterns. it might be easy to look at some analytical models and suggest they are too simplistic or do not account for “everything”. however, such statements are based on misunderstandings concerning the role of models as a means of analytical procedure, and the nature of the predictions derived from the theoretical parameters
on which they are based. Models are not by themselves statements about reality; rather they are formalised means of laying down explicit parameters in order that we can ask how much does reality match this pattern? Sometimes it will match the pattern with high degrees of fit; on other occasions, it will not match the data very well at all. Either way, we have made a manifest advance in our knowledge, being able to rule out or confirm the role of specific parameters and their strength of influence over a set of known variables.

**Cultural Transmission and Lineages of Artefactual Traditions**

The production of a concomitant set of artefacts constitutes the transmission of information or message ... A child brought up amongst motor-cars and skyscrapers is differently informed to another child born amongst stone axes and pig hunts


In recent years there has been a resurgence and growth of interest in issues of social transmission, the study of artefact lineages (i.e. diachronic “traditions”) and cultural phylogenetics (see e.g. O’Brien and Lyman 2000, 2003; Mace et al. 2005; Lipo et al. 2006; O’Brien 2008; Shennan 2000, 2009; Mesoudi et al. 2004, 2006). Quite correctly, such work frequently gives credit to the writings of figures such as Cavalli-Sforza and Feldman (1981) and Boyd and Richerson (1985) as sources of inspiration. As others have highlighted, however, such issues in the case of archaeological artefacts were of specific concern to David Clarke (e.g. Shennan 1989, 2004; O’Brien and Lyman 2000). Hence, somewhat ironically, despite being considered as part of the essential textual canon of the “New Archaeology”, Clarke’s (1968) own work continued to address issues more commonly associated with the preceding “culture-historical” approach, which of course was much maligned by what later became to be known as “Processual Archaeology” (Shennan 1989, 2004). In this sense, Clarke’s own version of “New Archaeology” was distinctive from that of others, and much of the current archaeological interest in issues of cultural transmission and the phylogenetics of tradition owes something of its heritage both to culture history and to Clarke’s *Analytical Archaeology* (O’Brien and Lyman 2000; Shennan 2000, 2004).

Contemporary “cultural evolutionary” approaches are based on three keystones: the social transmission of information (i.e. a mode of inheritance), variation in transmitted phenomena, and the subsequent sorting of variation which results in the unequal transmission of given variants through time (Eerkens and Lipo 2007). Figure 1.2a–c shows three modified versions of illustrations taken from *Analytical Archaeology*, which are particularly demonstrative of Clarke’s (1968) presaging of many issues perhaps only recently examined in earnest by those working in the cultural evolution or “evolutionary archaeological” framework. Despite this Clarkean ancestry, it is of course important to emphasise both the recent theoretical expansion of such a framework (frequently through empirical case studies) and the expansion of its analytical toolkit (Shennan 2004), the latter of which has frequently
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Theoretical expansions include greater emphasis on demographic factors affecting differential variant sorting through time (e.g. Lipo et al. 1997; Shennan 2000, 2001; Henrich 2004; Shennan and Bentley 2008; Lycett and Norton 2010), especially in regard to stochastic sorting mechanisms (i.e. “drift”) (e.g. Neiman 1995; Shennan 2001; Lycett 2008; Hamilton and Buchanan 2009). Additionally, more recent authors have tended to make explicit distinctions between cultural selection (both

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Fig. 1.2 (a–c) The concepts of social transmission, attribute variability in artefacts (and the sorting of such variation through time), and the creation of tradition lineages and cultural phylogenies, as envisioned by Clarke (1968). (a) The knapper possesses a set of concepts, ideas, craft skills, and knowledge that are employed in the manufacture of stone artefacts (Concepta). The artefacts are used in a set of roles or activities thus engaging with environment and context (Designata). The relationship between Designata and Concepta may be reciprocal. When learning a craft skill, the manufacturer is – via a process of social interaction – influenced by others, who in turn are ultimately influenced by the cumulative Designata and Concepta of previous generations. The artefacts produced vary within and between themselves in terms of a series of attributes. (b) Different attributes will have differing means, modes and standard deviations, and in turn these will vary within assemblages at different times. (c) The variations of attributes will change differently in different populations through time. This will lead to a diversification and branching of tradition lineages through time creating cultural phylogenies. (Redrawn and modified from Clarke 1968 (a) Fig. 39, p. 182; (b) Fig. 33, p. 171; (c) Fig. 20, p. 147. For definitions of Designata, Concepta, and Percepta, see Clarke 1968, p. 649)
conscious and unconscious varieties which may – but do not necessarily – affect biological fitness) and natural selection mechanisms operating on fitness directly (Cavalli-Sforza and Feldman 1981; Eerkens and Lipo 2005; Shennan 2006; for a discussion of these issues in relation to Palaeolithic artefacts see Lycett 2008).

Several chapters in the current volume discuss issues of social transmission and concepts of tradition in Palaeolithic technologies. Clarkson, for instance, argues that cores might preserve particularly high levels of information concerning the social transmission of technological traditions. As noted earlier, Clarkson tests directly the hypothesis that raw material is the dominant influence on the attributes of cores from the Howiesons Poort MSA of southern Africa, using a multivariate framework. In fact, Clarkson finds that using geographical region as a grouping variable actually results in higher classification scores than raw material, suggestive that regionally specific social traditions involved in core reduction are indeed preserved in the morphological attributes of cores from this period. Buchanan and Collard’s analyses similarly suggest that changes in Palaeoindian point morphology due to resharpening do not necessarily negatively impact classification scores. This leads them to conclude that resharpening techniques themselves, and/or socially held ideas surrounding blade shape, were influenced by factors that could have been influenced by cultural transmission. Lycett, meanwhile, discusses more fully the idea that methods and models used in biological settings to study the transmission of genetic patterns between generations can be constructively used in the analysis of Palaeolithic data.

**Morphometrics**

Put simply, *morphometrics* is the application of geometrical principles to the statistical study of morphology (Dryden and Mardia 1998). It bears repeating that every observation about the form of a stone artefact is an exercise in the description of morphology. Equally, knapped stone artefacts are – by definition – the product of hominin action interacting with a given raw material. In turn, accurate and detailed observations of stone tool form should lead us toward an increased understanding of both within-assemblage and between-assemblage variation, as well as the factors that lead to such variability, whether this be stochasticity, raw material, reduction intensity, function, ecology, cultural tradition, and cognitive and/or biomechanical differences.

As Clarke (1968: 528–530) recognised, in a practical sense, some of the problems involved in the quantitative process of artefact description are cognate to problems faced by biologists in the description of organismal form. In palaeontology (and biology in general) powerful mathematical and statistical methods of analysis are now routinely applied to detailed morphometric data sets, which allow secure assessments of intra- and inter-taxonomic variability, at both regional and global levels (e.g. O’Higgins 2000). Increased use of more sophisticated approaches
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to size adjustment (such that size may be analytically disentangled from shape; see e.g. Jungers et al. 1995; Falsetti et al. 1993), along with increased use of geometric morphometric methods in both 2D and 3D have led to what some have termed a “revolution” in biological morphometrics in recent decades (Adams et al. 2004; Jensen 2003; Rohlf and Marcus 1993).

In retrospect, therefore, it might be regarded as remarkably prescient of Clarke (1968: 528–530) that toward the end of Analytical Archaeology he included a picture and description of a “d-mac” tracer, which he believed could be of utility for the morphometric analysis of archaeological artefacts. He further wrote (1968: 530) of the future role of digitisation and scanning equipment, which in combination with computer technology, he suggested “are about to revolutionise the standard approaches”. Equally, prescient, however, he wrote “but [these] will doubtless take some time to infiltrate into archaeological studies” (1968: 530). Nevertheless, we might contend that even Clarke would be both surprised and disappointed to see just how long it has taken for archaeology to more seriously engage with these issues and methods.

As Costa and Iovita note in their respective chapters of this volume, morphometric approaches to lithic analysis have been employed by archaeologists for several decades, yet the extent of these approaches (both in terms of number of variables and number of artefact “morphs” studied within a single framework) has remained somewhat limited. In the case of the Lower Palaeolithic, for instance, other than some basic dimensions taken on flakes, the Bordes/Roe/Isaac system of biface measurements (e.g. Bordes 1961; Roe 1968; Isaac 1977) remains one of the few widely applied methodologies, yet is not easily adapted to allow the contiguous study of a wider range of artefacts. This, we are at pains to stress, does not mean such a system is without great value; many valuable insights into artefactual variation have been elicited via the use of such systems (e.g. Crompton and Gowlett 1993; Gowlett et al. 2001; McPherron 1999, 2003; White 1998; Brooks et al. 2006; Norton et al. 2006), and several studies in this volume make creative use of simple measurement data (Shott, Chauhan). Indeed, we might argue that not enough studies have utilised even straightforward methodologies such as this. Rather, what we would contend is that it is only until relatively recently that lithic analysts began to explore the potential of more sophisticated approaches to the description and analysis of stone tool form. Such contrasts are especially stark when compared with morphometric developments that have taken place, for example, in Palaeolithic archaeology’s sister discipline of physical anthropology (Slice 2007).

Several potential reasons for the relatively slow adoption of more sophisticated morphometric methods in lithic studies might be offered. One is simply the difficulties of using expensive precision and digital equipment in conjunction with the high levels of dust and grit that are frequently associated with lithic collections,

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3See Wynn and Tierson (1990) for a rare example of a methodology that attempts to go beyond the standard measurement scheme for bifaces.
both in the field and lab (e.g. McPherron and Dibble 2003). A further reason might be the general suspicion and lack of interest mentioned earlier that is sometimes associated with quantitative methods, as might the lack of relevant training. However, while such reasons might have been in operation, we suspect these are less pertinent than a more fundamental problem. In the case of biological forms (especially skeletal structures), there are frequently a large number of readily identifiable points of correspondence, or “homologous landmarks” (e.g. the junctions of cranial sutures), which can be seen across a range of different taxa, even in the face of what might sometimes be quite disparate morphologies. Sadly, this cannot be said so easily in the case of stone artefacts, as both Ioviţă, and Monnier and McNulty note in this volume.

A concept of correspondence or “homology” (i.e. that the features being measured in one specimen are directly analogous to those measured in another) is of course crucial to any morphometric analysis. In the field of biology, the ready identification of suitable landmarks enables the calculation of multiple inter-landmark distances, which can subsequently be size-adjusted [e.g. by the geometric mean (Jungers et al. 1995)] in order to create shape variables. Such variables may then be analysed using a variety of parametric and multivariate statistics. Alternatively, landmark coordinates may be analysed via a geometric morphometrics framework. Geometric morphometrics is the analysis of landmark configurations following standardization of their orientation, position and scaling (Slice 2007). Several freely available programs are now available for this purpose. The resulting shape variables can then be inputted to a multivariate statistical analysis.

The lack of easily defined points of homology on stone artefact forms is thus debilitating to the straightforward application of several morphometric methodologies seen in other fields. As Ioviţă notes in this volume, lithic analysts have been inventive in overcoming some of these impediments in recent years (Buchanan 2006; Clarkson et al. 2006; Lycett et al. 2006), and the contributors to this volume present a range of solutions to this problem. Several contributors here for example use what are termed “semilandmark” approaches (Buchanan and Collard, Costa, Monnier and McNulty). Terminologically, Bookstein (1991: 63–66) originally identified three categories of landmark. Type I landmarks were those readily identifiable points (e.g. cranial suture junctions) that required no geometric definition in relation to other aspects of the specimen. Type II landmarks were identified as morphologically isolated points or extremities (e.g. the tips of extrusions or invaginations). Type III landmarks were regarded as geometrically defined points, and thus are identified instrumentally. An important point here is that “homology” is not

4Confusingly, the term “homology” has several distinct meanings in both biology and archaeology (Lycett 2009). Use of the term “homology” in the sense of landmark correspondence across forms should not be confused with “phylogenetic homology” resulting from shared ancestry (see O’Brien, this volume).

5See e.g., http://life.bio.sunysb.edu/morph/
necessarily an inherent or conveniently identifiable property, but something that may emerge from a clear but operationally specified definition (O’Higgins 2000). Subsequently, Bookstein (1997) renamed Type III landmarks as “semilandmarks”. Semilandmarks can conceptually be thought of as homologous in the sense of being geometrically correspondent across forms. Hence, via the use of explicit geometric protocols for their identification, the locations of semilandmarks are driven by the observed morphology, thus effectively capturing morphological similarities and disparities across specimens.

In addition to semilandmark methods, Iovită points out the utility of outline methods – in this case Fourier analysis – as a means of overcoming landmarking issues in the case of stone tools. As Iovită notes, given that many questions concerning stone tool form might be addressed via an examination of outlines, it is somewhat surprising that archaeologists have not made more extensive use of such methods. Meanwhile, Clarkson and Lycett show in their respective chapters how a range of quantitative attributes, including several with a long history in lithic studies, can be employed alongside novel attributes in multivariate frameworks of analysis. Clarkson’s chapter includes discussion of how core angles may be captured quantitatively using digitizing equipment (Microscribe™, Immersion Corp., San Jose, USA) more typically used for capturing landmark data (see also Clarkson et al. 2006). In a similar vein, Braun and colleagues describe a method for capturing flake platform areas using such equipment. These examples show that the use of new morphometric procedures in contemporary lithic analysis involves not only the adoption of existing methods employed in other fields (as useful as that may be) but is also creatively finding new means of addressing problems unique to the study of stone artefacts.

In sum, the judicious use of new morphometric methods may open novel lines of enquiry, allowing stone artefact parameters to be quantified more extensively and more accurately than ever before. It must be remembered, of course, that morphometrics is no panacea for the problems faced by lithic analysts; we must still be measuring analytically relevant variables (Lycett 2009; Braun this volume). However, it must be equally remembered that what gives a variable relevancy is not inherent properties per se, but the construction of a theory or model that allows patterns created by measurement procedures to be compared for goodness-of-fit or statistical significance, in line with the predictions of the hypothesis or model (Clarke 1968; Hill 1972). Rather, given that artefacts are – by definition – the product of human action, the number of variables that are analytically irrelevant can only be determined in the context of the analytical framework used. A more immediately pressing concern might therefore be the construction of testable hypotheses and models, whether these are dependent upon prior observations, ethnology, ethnography, experiment, or evolutionary, ecological and social theory. What morphometric methods do, we would contend, is open up the range of possibilities in which lithic analysts can relate such hypotheses and models to empirical data.

Along with an ensemble of recent work (e.g. Saragusti et al. 2005; Buchanan 2006; Clarkson et al. 2006; Lycett et al. 2006; Lycett 2007; Iovită 2009), we believe the
chapters in this book are indicative that a “revolution” in lithic morphometrics is in progress, equivalent to the one undergone in biology in recent decades (Jensen 2003; Rohlf and Marcus 1993), and along the lines envisioned by Clarke over four decades ago. In the case of the Palaeolithic, there is often an emphasis on obtaining new data via new fieldwork, and of course such endeavours are essential to the discipline. However, in physical anthropology countless students and professionals set out year after year to measure the same primate and human skeletal collections, yet all are tackling different questions, often with a variety of methods. Many lithic collections derived from field survey and excavation currently languish in universities and museums around the world. An increase in morphometric studies may further increase (and encourage) greater analytical potential to be derived from such collections, thus extending their value as research resources.

Conclusions

The current volume has two sides. On the one hand, several innovative techniques and novel perspectives are presented. Yet on the other, they appear to be guided by certain general philosophical principles whose origin in the discipline can be traced, at least in part, to a volume (Clarke 1968) published at a date prior to which the majority of contributors to this volume were even born.6

It is probable that disagreements on certain finer points are evident in the views of some contributors. However, we believe there is sufficient common ground under the general philosophical approach taken by the contributors that even such disagreements are providing fruitful future lines of enquiry rather than descending into irresolvable polemic. The “general philosophical approach” we speak of is, of course, one guided by formal analysis, hypothesis testing, model building, quantification and statistical approaches. These are themes that we believe David Clarke would recognise, and we hope, be content to see them in active operation today during the analysis of Palaeolithic data. For via their application, it appears that new perspectives on old stones may emerge.

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6 In the interests of discretion, we will leave it to the reader to work out for themselves which authors do not fall into this category!
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