

ARCHAEOOMETRY AND MATERIALITY: MATERIALS-BASED ANALYSIS IN THEORY AND PRACTICE*

A. JONES

Department of Archaeology, University of Southampton, Highfield, Southampton SO17 1BF, UK

Due to the diversity of contemporary archaeology, the aims and approaches of archaeological scientists and archaeological theorists are often at odds. I suggest that this position is problematic, both intellectually and methodologically, as both groups are fundamentally engaged in the same task: an understanding of past societies through the medium of material culture.

This paper offers a review of the intellectual positions of both groups, with a brief discussion of the history of archaeological theory and an appraisal of its current trajectory. I will discuss how and why contemporary theoretical perspectives have fundamentally diverged from the perspectives of archaeological scientists and how the recent theoretical emphasis upon materiality offers a rapprochement between theoreticians and archaeological scientists.

KEYWORDS: ARCHAEOLOGICAL SCIENCE, THEORETICAL ARCHAEOLOGY,
POST-PROCESSUALISM, LINGUISTIC METAPHORS, MATERIALITY,
EMBEDDED TECHNOLOGIES, PERFORMANCE CHARACTERISTICS,
COLOUR SYMBOLISM

INTRODUCTION

Contemporary archaeology is an extremely diverse discipline, encompassing interest groups focusing on distinct periods, regions, theoretical perspectives and methodological techniques. This diversity is a positive development, but it can carry with it problems of communication; different components of the discipline are arguably talking quite different languages (Schiffer 1996; Brown and Pluciennik 2001). One of the most persistent of these problems of communication lies between archaeological theorists and archaeological scientists (Edmonds 1990; Thomas 1990; O'Connor 1991; Dunnell 1993).

In this paper, I want to review the intellectual positions of both groups, with a brief discussion of the history of archaeological theory and a consideration of its current trajectory. I will discuss how and why contemporary theoretical perspectives have fundamentally diverged from the perspectives of archaeological scientists and how the recent emphasis upon materiality in interpretative archaeology may enable a *rapprochement* between theoreticians and archaeological scientists. Although my discussion will largely consist of a commentary upon recent archaeological theory and its relation to science-based archaeology, I will also provide some case studies as pointers towards a hoped-for future direction.

* Received 10 October 2003; accepted 11 March 2004.

© University of Oxford, 2004

POST-PROCESSUAL ARCHAEOLOGY AND ARCHAEOLOGICAL SCIENCE

I will begin by considering theoretical orientations in post-processual (or interpretative) archaeology (Tilley 1993) and their relationship to archaeological science. We begin our discussion with the publication of *Symbolic and structural archaeology* (Hodder 1982), since this volume arguably marks the emergence of post-processual archaeology. Post-processualism was formulated as a critique of processual models of the past, which tended to view material culture as a passive outcome of the economic and adaptive concerns of past social groups. As an alternative, early post-processual accounts of the past acknowledged that material culture was both meaningful and active in the constitution and creation of social relations (Hodder 1986). But how was material culture to be studied? Importantly, early post-processual writers borrowed a linguistic (or textual) metaphor for material culture from structuralist and post-structuralist thinking in anthropology and sociology. This metaphor led archaeologists to treat artefacts as if they communicated meaning like language. Thus, the sequences of designs on pots or, at a greater level of abstraction, the layout of households, villages, burials and cemeteries were all in their turn treated as a form of 'silent grammar', whose logic remained to be decoded by archaeologists (Tilley 2002, 23–4).

If we are to understand the problem that lies at the heart of the relationship between theoreticians and archaeological scientists, the linguistic approach to material culture pays closer attention.

Archaeologists, like anthropologists before them (Leach 1973), had borrowed their version of semiotics from the French structural linguist Ferdinand de Saussure. Saussure posited that language, as a discourse or system of meaning, consists of a series of words (or phonemes) that bear an arbitrary relationship to the object that they signify. The most commonly quoted example, in terms of language, is that the word 'dog' is not a descriptive term that describes the animal in detail. In fact, any other word could be substituted to stand for 'dog', and indeed other words such as 'chien' and 'hund' are used in other languages such as French and German to signify the same object. An arbitrary relationship exists between the object signified (known as the referent) and its meaning as a sign. The term used in any language is simply significant in relation to other terms in that language. Put simply, language is an abstract code with an arbitrary relationship to the world of objects. This perspective is fine when discussing linguistics and arguably works equally well for the analysis of culture in anthropological terms.

However, we run into a series of problems when we apply this perspective to the analysis of material culture. Surely the meaning of (say) pottery is not arbitrary, but is at least partly determined by its material qualities. The linguistic or textual metaphor has its limitations, as it treats the material world as a mere substratum on to which humans lay their ideas and concepts. Arguably, while the intention of the early post-processualists was to conjoin the material and social worlds, due to a close adherence to linguistic models, the physical aspects of material culture remain relatively passive in their accounts of the past. Material culture therefore only had meaning as components of abstract communicative systems: the material qualities of objects and the way in which they impinged upon human beings was not fully acknowledged. I will return to this point below.

More seriously, the adoption of the linguistic perspective has tended to promote a disjuncture between the frameworks of theoretical archaeologists and science-based archaeologists. As a result, the aims and methods of both groups have diverged. This is because, for theoreticians, the material qualities of artefacts do not necessarily determine their meaning while, for

science-based archaeologists, the material properties of the archaeological record form the meat and drink of their studies.

Elsewhere, I have described how these differing perspectives relate to fundamentally different philosophical platforms, one founded on idealism and the other on empiricism (Jones 2002a). It is worth briefly revisiting these arguments, as they help to clarify the differing perspectives of the two interest groups under discussion.

For Western philosophical traditions, the world is perceived to be composed of two things with differing properties—generally described as objects and subjects. The natural world, the world of objects that exists prior to its description by subjects, is viewed as inanimate and immutable. The world is also composed of subjects who, in contrast, are considered to be animate and are therefore invested with the ability to act and describe the inanimate world of objects. Fundamentally, the division between the approaches of theoreticians and archaeological scientists is founded upon this worldview; sciences study the behaviour and properties of objects, while the arts and humanities are concerned with the study of subjects.

Related to this division of labour are the philosophical positions of objectivism and subjectivism. An objectivist viewpoint proposes that the world consists of objects that exist external to the internal world of human subjects. The properties and relationships between these objects can be adequately captured by language. Fundamental to this view is the notion of empiricism; that the relationship between our language terms and the world is direct and unproblematic. A subjectivist view proposes otherwise. What if our perception of the world is not direct? What if we cannot extricate ourselves from the world in order to describe it? If processes of acculturation condition our senses, to what extent do these processes of acculturation affect the linguistic categories that we employ to describe the world? Subjectivism is therefore founded upon a position of idealism, that the cultural categories or ideas used by human beings condition their engagement with the world.

It is therefore easy to see that the linguistic or textual paradigm in archaeology is allied to an idealist and subjectivist position, while the theoretical position that underpins much archaeological science is empiricism and objectivism. This state of affairs may be seen as acceptable by some, and this general intellectual and disciplinary division is tolerated in many subjects, such as psychology and anthropology. Some disciplines, such as anthropology, divide themselves into distinct subject areas studying quite different phenomena: biological anthropologists study the biological evolution of humanity, while social anthropologists study the worlds of meaning that humans create for themselves (although for an attempt to close this intellectual gap in anthropology, see Ingold 2001). I would argue that in some senses archaeology is different. At the most practical level, this is because whatever intellectual positions archaeologists take up, they ostensibly all study the same phenomenon: material culture.

As Prown (1996) notes, the term 'material culture' encapsulates a contradiction. As we have seen, we operate within a philosophical and disciplinary framework that makes a logical distinction between the inert matter of the natural world and the ideas and categories that make up the cultural world. If 'culture' is a set of ideas, categories and frameworks created through inter-subjective relationships amongst humans, how is it possible to have *material* culture? I will address this question in more detail below. At this juncture, we simply need to note that at both the practical and theoretical level we are required to simultaneously consider how it is that artefacts are socially and culturally constructed, while also taking into account the physical and mechanical construction of artefacts. We do not need to study these two aspects of artefacts as separate and distinct entities. Materials science and material culture studies are therefore engaged in the same project of enquiry.

MATERIALITY AND ARCHAEOMETRY

Problems with the linguistic approach to material culture are beginning to be felt. Chris Tilley, one of the main proponents of the linguistic or textual approach (e.g., Tilley 1991) has recently noted that language cannot be used as the sole model for understanding the material world. As he aptly puts it, designs are not words, and houses are not texts (Tilley 2002, 23). Although related, language and the material world are experienced and understood in different ways. The linguistic metaphor for material culture is also problematic if, as noted above, we embrace the point that the term 'material culture' embodies both an objective and subjective dimension. Is it still viable to utilize a framework formulated for the analysis of language and culture for the analysis of physical artefacts?

A new approach to some of these problems arose in the mid-1990s and was arguably crystallized by Chris Gosden (1994) in the volume entitled *Social being and time*. Here, questions arose concerning the concept of *materiality*. What is meant by the term *materiality* and how does it differ from previous approaches? In essence, the notion of materiality encompasses the view that material or physical components of the environment and the social practices enacted in that environment are mutually reinforcing (see also Jones 2002a, 168–82; Boivin forthcoming). The material world, and the social practices that take place in that world, bring each other into being and are therefore analytically indivisible (see also Miller 1987).

This is not to say that we should treat the material environment as determining human behaviour—materials both constrain and enable human activity (Gosden 1994, 77). The notion that the material world has an influence upon humans has elsewhere been described as a form of *material agency* (Latour 1993; Pickering 1995; Gell 1998; Jones 2002a). Acknowledgement of the materiality of material culture has a dual function. It promotes the view that the material qualities of the environment actively affect how they are perceived, used and symbolized, and—importantly—it emphasizes how those material properties are enrolled in the life projects of humans. Furthermore, it promotes a historical perspective to the processes of interaction between person and environment.

This is emphasized in an example used by Latour (1999, 186–7). He discusses the concrete speed bumps laid down in certain residential areas to limit the speed of passing traffic, in order to reduce accidents. These simple lumps of concrete—often known as 'sleeping policemen'—provide mute testimony to the concept of material agency. Latour describes them as the translated material form of the intentions and actions of road traffic officials. This example is useful, as we observe how the intentions of people are translated into material form, which then affect subsequent human intentions. Pickering (1995) describes this interaction between the social and material worlds as one of accommodation and resistance. By turns, people will accommodate or resist in their interaction with the environment, while the environment will likewise accommodate or resist human action (for extended discussion of this concept, see Jones 2002a, 168–82).

Arguably, this perspective shifts the nature of the whole archaeological project. Artefacts are no longer just clues to be decoded, which will enable us to reconstruct past human behaviour: instead, artefacts are integral components of the past, which were shaped by, and in turn helped to shape, human behaviour (see also Boivin forthcoming). The critical point here is that the notion of materiality strikes a very different tone to the linguistic approach: the material qualities of material culture are central to how they are used and made meaningful. What does this shift in perspective mean for archaeometry and science-based archaeology as a whole?

The first thing to point out is that the physical and mechanical properties of material culture have always been of prime concern to archaeometry and science-based archaeology. In fact, the initial development of an archaeometric or materials-based approach in archaeology involved the importation of expertise from the physical sciences, such as chemistry and physics (Tite 1972) and geology (Peacock 1969a,b; 1982). The success of these approaches is perhaps exemplified by the useful translation of tried and tested techniques of characterization, such as petrology, to archaeological problems—often with spectacular results (Peacock 1969a,b; 1972). The adoption of techniques from the physical sciences has continued with ever more refined methods for characterizing the chemical, physical and mechanical properties of artefacts (Cotterell and Kamminga 1990; Kingery 1996; Pollard and Heron 1996; Henderson 2000). It seems fundamental, and indeed obvious, that the material qualities of artefacts have a critical affect upon their use and perception (Tite *et al.* 2001). That assumption underlies many characterization studies. A perspective that has seen less emphasis is how these material properties interrelate with the social and cultural lives of the people who made, exchanged, used and deposited artefacts. It is this close attention to the interwoven nature of the social and the material that I believe to be novel to the concept of materiality.

Fundamentally, this recent theoretical perspective allows us to begin formulating projects that treat the material qualities of material culture as central. Just as the notion of materiality encompasses the process by which the conceptual and material are woven together, we need to interweave the conceptual and materials-based components of the discipline in our analyses. What kinds of projects might these be? I will point the way by using a couple of examples and then go on to discuss, in a more general sense, possible areas of future development.

My first example comes from outside the strict confines of archaeometry, but admirably illustrates the approach that I am advocating. Nicole Boivin's research focuses on soil micromorphology, and her main area of study has been ethnoarchaeological studies of soil and clay use in the context of architecture in rural Rajasthan, India (Boivin 2000). In rural Rajasthan, houses are generally constructed from mud. Constructions are therefore relatively ephemeral and require constant maintenance through re-plastering and rebuilding. While Boivin's work offers a conventional soil micromorphological description of the layers and walls used to construct these houses, she also discusses how soil shapes rural Rajasthani society. There are two levels at which she discusses this phenomenon. First, the malleable nature of mud means that houses are highly fluid, organic spaces in which the divisions, walls, rooms and other features are added, removed or altered as the family unit occupying the house changes in size. Mud here is eminently malleable, but due to its plasticity it also serves to shape the experience of household space amongst rural Rajasthani communities.

As well as shaping the experience of space, soil is also used to shape the experience of time. Boivin discusses the way in which soils of different colours are used to transform households. She describes how the use of two soils of differing colours, called *Doli mitti* and *Pili mitti*, are used at different stages of the yearly cycle to redefine the household space. *Doli mitti* is used every day, while *Pili mitti* is an embodiment of *Laksmi*, the Hindu goddess of wealth, and is used on auspicious occasions. The practice of re-plastering floors with soils of differing colours fuses spatial and temporal experience. The daily and seasonal cycles of re-plastering frame and articulate lived human life cycles. Births, initiation rites, weddings and deaths are all marked by re-plastering events; the very experience of time is cued by the use of certain types and colour of soil. These interpretative conclusions are the result of an explicit focus on the material nature of soil and mud, and arise neither just from soil micromorphological or ethnoarchaeological analysis; rather, they are the outcome of the use of both techniques in concert.

A superb example of the way in which issues of materiality are complimented by archaeometric techniques is provided by Dorothy Hosler (1993), who has investigated the relationship between colour and luminosity and techniques of metal winning and production in historic west Mexico. Colour and luminosity have been noted to be of critical importance in historic Mesoamerica (Saunders 1998, 1999, 2002; Brumfiel forthcoming). Tin and arsenic were alloyed with copper in the technologies of numerous peoples in historic Mesoamerica. The concentration of the alloying element (tin or arsenic) was so high (22 wt%) that it altered the metallic colours so that the artefacts looked golden (copper–tin bronze) or silvery (copper–arsenic bronze). Gold was associated lexically to the power of the sun and silver to that of the moon. The use of alloys in such high concentrations was unnecessary either to achieve the castings or to the functionality of the cold-worked items, so that these highly reflective colours became a cultural end in themselves. Colour is here a significant component of the materiality of metal and it has a critical effect upon its valuation for both indigenous Mesoamericans and the colonial Spanish (Saunders 1999).

Hosler's metallurgical analyses confirm and add quantitative weight to these qualitative discussions concerning the cosmological and social significance of alloying. She goes further than this, with a contextual analysis of the kinds of objects made of metal—especially bells and rattles—and relates them to beliefs in the creative power of thunder and rain (see also Palmer *et al.* 1998). The important point here is that Hosler's investigations foreground the physical qualities of materials. In her analyses, metals such as gold, copper and silver are not simply treated as convenient materials for the production of certain artefacts; rather, the treatment and use of metal is considered as axiomatic to a wider understanding of historic west Mexican society. By placing metal at the centre of her analysis, she asks how the material qualities of metal shape the Mesoamerican worldview, and how this worldview in turn shapes the production of artefacts from metal.

Another example from the field of archaeometry relates to work conducted by the National Museum of Scotland, by Alison Sheridan and Mary Davis (Sheridan and Davis 1998, 2002). They have been concerned to characterize the materials used in the striking jet necklaces from Early Bronze Age mortuary contexts in Scotland and Wales, using XRF and xeroradiography. Their project has two aims:

- (1) To understand the geological origin of the material used in jet necklaces.
- (2) As a secondary consequence of this analysis, to gain an insight into the life history or biography of these objects.

The results of these analyses have been remarkable. Many of the necklaces in Scotland and Wales were provenanced from the major source of jet in Whitby, Yorkshire. In some senses, this was expected. More surprising was the evidence that components of these necklaces had often been mended with 'inferior' local substances such as cannel coal. This conclusion is especially important, since it underlines one of the essential aspects of the materiality of these objects—they are constructed of distinct components and can be curated, and therefore have extensive life histories. This means that they can be used to speak of social relations established between generations. They are in effect heirlooms (Parker-Pearson 1999, 85–6; Jones 2002b). This accords well with the kind of contexts in which we find them, deposited in graves with a single individual, as complete necklaces or as fragments.

Again, we observe a mode of analysis that highlights the materiality of artefacts. Research was here focused on traditional questions of characterization and provenance. However, because the analysis was sensitive to the material qualities of the artefacts, the study provides an analytical platform to incorporate both science-based techniques and post-processual frameworks of analysis.

I hope that these examples have illustrated the kind of material-based analysis that might incorporate materiality as a primary focus.

Although materiality may not have been an explicit theoretical framework for all of these examples, each one indicates an analytical focus upon the qualities of artefacts, which enables us to consider how those qualities are interwoven with social practices and cultural beliefs.

ARCHAEOOMETRY AND MATERIAL CULTURE ANALYSIS

The field of materiality is almost limitless in terms of the object of our analyses. However, I want to conclude by outlining some possible ways in which archaeometric analyses or techniques might capture the sense in which the material qualities of material culture affect its social use and cultural perception. I define material culture here in its broadest sense, to include portable artefacts and architecture.

Production

Key questions relating to the issue of materiality and production include the following. Do the physical properties of different materials have an effect upon the way in which materials are worked? The concomitant of this initial question is: How do the physical properties of different materials affect the organization of production? Here, investigation needs to centre not only on the characterization of the physical attributes of artefacts but also on how these attributes relate to production sequences and their organization. The notion of materiality connects us with research related to technological choice, *chainés opératoires* and the organization of production (Tite 1999). In many ways, questions relating to materiality and production have already been well discussed, both in the theoretical and the scientific literature (Lemonnier 1992, 1993; Dobres and Hoffman 1994; Dobres 2000; Sillar and Tite 2000).

The first of the questions posed above is fundamental to archaeometry and has been addressed in innumerable studies, while the second of these questions is less often posed. The relationship between artisans and their environment has long been a concern of archaeological scientists, as we observe in the 'ceramic ecology' paradigm of Matson, Arnold, Kolb and others (Matson 1965; Arnold 1985, 1993; Kolb 1989). Ceramic ecology is best articulated by Arnold (1985, 16–18). For Arnold, 'the basic assumption is that relationships between the technology (in this case, the ceramics) and the environment must be worked out before ceramics can be related to the rest of the culture' (*ibid.*, 16). To understand this relationship, he adopts a cybernetic or ecological perspective that looks at the feedback mechanisms that occur between cultural behaviour and the environment.

Fundamentally, the focus of this research is excellent; however, I would diverge from an explicitly 'ecological' approach since I believe it places too much emphasis upon the determining character of the material world. Interestingly, Sillar and Tite (2000) address this very point with the notion of 'embedded technologies'. The notion of embeddedness in relation to technology encompasses the point that 'every technique is part of a wider context of artefacts, environments, ideologies, economic systems and social structures' (Sillar 2001, 291). The environment is not simply determining; rather, the relationship between the person and the world is mutually entangled—the world is active in constituting social relationships, just as people are active in shaping the form of the environment that they inhabit. In relation to my discussion above, I would emphasize the interaction between the physical properties of the

materials used in manufacturing material culture and the social practices involved in their manufacture as critical areas of enquiry.

Colour

One specialized aspect of production technology is colour. The subject of colour has arisen as an interesting new development in the field of material culture studies. Here, interests relate to colour symbolism and the visual effect of colour (Jones and MacGregor 2002). However, surprisingly little work has been undertaken on the physical properties of colour, or on the extent to which colour is selected for during artefact production. It is worth noting that although theoreticians have been slow to address this problem, archaeometrists have long been discussing the question of colour.

The analysis of pigments in frescos and building plasters is a common subject of enquiry (Béarat 1996; Del Monte *et al.* 1998; Rosalie David *et al.* 2001; Damiani *et al.* 2003), as is the utilization of pigments for rock art or cave art (Jercher *et al.* 1998; Pomiès *et al.* 1999). Analysis of colour in manuscripts, such as the Dead Sea Scrolls, is less common (Nir-El and Broshi 1996). By far the greatest application of archaeometric techniques to the analysis of ancient colour is in the analysis of artefacts. Here, analysis focuses mainly on artefacts made of coloured substances, such as faience or glass (Vandiver 1983; Tite and Bimson 1986; Tite 1987; Shortland 2000, 2002; Shortland and Tite 2000; Rehren 2001; Heck *et al.* 2003; Tite and Shortland 2003).

While these studies have all concerned themselves with questions relating to the deliberate selection of colour during production, and the control of technological procedures to achieve a specific colour effect, there has been less emphasis upon the symbolic or affective dimensions of colour. One exception to this is the discussion by Jercher *et al.* (1998) of the cosmological significance of colour in Aboriginal Australian cultures, which forms a background to a sourcing programme using XRF and XRD on ochre from burials and artefacts. Nevertheless, despite the fact that the background to this research is grounded in a need to understand the cosmological role of colour, and despite the impressive results yielded, it unfortunately fails to utilize these results to enrich our understanding of Aboriginal perspectives on colour symbolism and cosmology. This division of intellectual labour is partly symptomatic of the division between archaeological scientists and their theoretical cousins. Here, I am arguing for a much closer integration of analytically derived data with theoretical argument.

Use

The mechanical properties of objects—plasticity, malleability, fragmentation and thermal and mechanical shock resistance—are again fundamental subjects of enquiry for archaeometrists (e.g., Anders *et al.* 1992; Bradley *et al.* 1992; Kilikoglou *et al.* 1998). These factors are obviously fundamental to questions of materiality, since at a primary level they affect the choice of the materials are used, and how they are used. While excellent work has been conducted on the performance characteristics of various artefacts, emphasis needs to be placed upon the way in which performance characteristics affect the way in which artefacts are employed socially. One example of this is John Chapman's recent discussion of object fragmentation in the Neolithic and Chalcolithic of the Balkans (Chapman 2000). Chapman proposes that the abundance of fragmented objects at sites of these periods does not result solely from accidental breakage, but largely from deliberate acts of fragmentation. He suggests that the fragmentation and sharing

of object fragments is one means by which social relations are created and maintained during this period of prehistory. His argument is compelling and detailed, but lacks the analytical and technical studies of specific materials to confirm and enrich the overall thesis. The point here is not that materials are either made with functional or social uses in mind but, rather, that the mechanical properties of artefacts either enable or constrain their use in certain social practices. It is the interaction between the properties of materials and the way in which they are socialized that is critical here.

Durability

Related to the study of the performance characteristics of artefacts is the question of durability. Durability is assumed to be a desirable aspect of the mechanical properties of most artefacts. But to what extent are particular materials chosen for making artefacts because of their ability to endure? As Miller (1994) has noted, the meaning of objects is closely related to their temporal connection to people; they may be transient, have a high longevity or have a close temporal relationship. This temporal connection has a distinct bearing on the physical characteristics of objects. In a contemporary setting, we might expect transient artefacts to be made of plastic, while objects meant to endure would be made of stone or concrete. Questions of durability do not simply relate to utility and function: durability is also a socially meaningful quality of artefacts, since it determines how artefacts are valued, used and exchanged, as well as the extent to which artefacts are involved in acts of commemoration. One of the clearest indications of this comes from the ethnography of Madagascar, where the sequential use of wood and then stone in house construction is used to speak of the endurance and strength of marital and familial ties (Bloch 1995). In a similar way, the translation of wood monuments into stone during the British Neolithic and Bronze Age is likewise a commemorative statement (Thomas 2000; Bradley 2002). Again, these considerations need to be kept in mind when studying the performance characteristics of material culture, since the perceived temporal relationship between artefacts and persons has considerable bearing on their material composition.

CONCLUSION

In many senses, I am preaching to the converted. Materials-based analysis forms the very basis of much science-based archaeology. In contrast, theoretical archaeologists have come late in the day to realize that artefacts are much less a phenomenon on to which ideas are mapped; rather, it is the very physicality of the archaeological record, in the form of artefacts and architecture, that is the strength of the discipline. This is not to say that the linguistic metaphor for understanding the meaning of artefacts is redundant: it is simply one facet of our understanding (for an attempt to move beyond the linguistic metaphor, see Tilley 1999).

If the materials-based framework that I have been discussing here is to be fully realized, it is vital that the approaches of theoretical archaeologists are harmonized with the analyses of science-based archaeologists. The opportunity exists for exciting projects that place the question of materiality at their centre. The emphasis here should be on a symmetrical form of analysis that focuses not only on the description and characterization of the material properties of artefacts (the traditional preserve of archaeometry), but also on how those material properties intervene in the social lives of people (the traditional concern of theoretical archaeology). Such a symmetrical approach would lead to the consideration of questions such as the following:

How are the material properties of artefacts symbolized? How do they help to influence the form that social relations take?

For example, to what extent does the adoption and use of a material substance such as clay affect Neolithic social relations? How does it enable some social possibilities and impose certain constraints? By focusing on clay as a substance, we can begin to conjoin hitherto distinct questions relating to cooking, storage, feasting, fragmentation, figurine production, procurement, performance characteristics and the use of clay as a building resource (see Boivin forthcoming). To what extent do these distinct aspects of clay as a resource inform each other? Does the plasticity of clay and its use as a variety of pottery containers promote new culinary regimes? To what extent does the malleability of clay as a resource enable the world to become more compartmentalized in terms of houses, rooms, storage containers and pots? How does the use of clay in this way relate to social reproduction?

Equally, similar questions could be asked of the early adoption and use of metals. How does the malleability, mining, production, transformation, hardness and lustre of a metal such as copper relate to the production of weaponry and the Bronze Age warrior ethos? How do social relations alter with the circulation and use of metal? To what extent does the materiality of metal inform its use in certain contexts, such as grave assemblages?

Questions are being asked of materials from a variety of social perspectives: it remains now to integrate social questions with material analyses. If we assume that a focus on materiality places the material qualities of artefacts at the centre of a web that ties together questions relating to social relations, symbolization, physical interactions with the environment and subsistence, then we have an extremely powerful analytical tool.

REFERENCES

- Anders, G. J. P. A., Jorg, C. J. A., Stern, W. B., and Anders-Bucher, N., 1992, On some physical characteristics of Chinese and European red wares, *Archaeometry*, **34**, 43–52.
- Arnold, D. E., 1985, *Ceramic theory and cultural process*, Cambridge University Press, Cambridge.
- Arnold, D. E., 1993, *Ecology and ceramic production in an Andean community*, Cambridge University Press, Cambridge.
- Béarat, H., 1996, Chemical and mineralogical analysis of Gallo-Roman wall painting from Dietikon, Switzerland, *Archaeometry*, **38**, 81–95.
- Bloch, M., 1995, Questions not to ask of Malagasy carvings, in *Interpreting archaeology: finding meaning in the past* (eds. I. Hodder, M. Shanks, A. Alexandri, V. Buchli, J. Carman, J. Last and G. Lucas), 212–15, Routledge, London.
- Boivin, N., 2000, Life rhythms and floor sequences: excavating time in rural Rajasthan and Neolithic Catalhöyük, *World Archaeology*, **31**(3), 367–88.
- Boivin, N. forthcoming, Mind over matter? Collapsing the mind–matter dichotomy in material culture studies, in *Rethinking materiality: the engagement of mind with the material world* (eds. C. Gosden, E. DeMarrais and C. Renfrew), McDonald Institute Monographs, Cambridge.
- Bradley, R., 2002, *The past in prehistoric societies*, Routledge, London.
- Bradley, R., Meredith, P., Smith, J., and Edmonds, M., 1992, Rock physics and the Neolithic axe trade, *Archaeometry*, **34**, 223–35.
- Brown, K. A., and Pluciennik, M., 2001, Archaeology and human genetics: lessons for both, *Antiquity*, **75**, 101–6.
- Brumfiel, E. forthcoming, Meaning by design: ceramics, feasting and figured worlds in Postclassic Mexico, in *Rethinking materiality: the engagement of mind with the material world* (eds. C. Gosden, E. DeMarrais and C. Renfrew), McDonald Institute Monographs, Cambridge.
- Chapman, J., 2000, *Fragmentation in archaeology*, Routledge, London.
- Cotterell, B., and Kamminga, J., 1990, *Mechanics of pre-industrial technology: an introduction to the mechanics of ancient and traditional materials culture*, Cambridge University Press, Cambridge.
- Damiani, D., Gliozzo, E., Memmi Turbanti, I., and Spangenberg, J. E., 2003, Pigments and plasters discovered in the House of Diana (*Cosa*, Grosseto, Italy): an integrated study between art history, archaeology and scientific analysis, *Archaeometry*, **45**, 341–54.

- Del Monte, M., Ausset, P., and Lefevre, R. A., 1998, Traces of ancient colours on Trajan's Column, *Archaeometry*, **40**, 403–12.
- Dobres, M.-A., 2000, *Technology and social agency*, Blackwell, Oxford.
- Dobres, M.-A., and Hoffman, C., 1994, Social agency and the dynamics of prehistoric technology, *Journal of Archaeological Method and Theory*, **1**(3), 211–58.
- Dunnell, R. C., 1993, Why archaeologists don't care about archaeometry, *Archeomaterials*, **7**, 161–5.
- Edmonds, M., 1990, Science, technology and society, *Scottish Archaeological Review*, **7**, 23–31.
- Gell, A., 1998, *Art and agency: an anthropological theory*, Oxford University Press, Oxford.
- Gosden, C., 1994, *Social being and time*, Blackwell, Oxford.
- Heck, M., Rehren, Th., Hoffmann, P., 2003, The production of lead–tin yellow at Merovingian Schleithem (Switzerland), *Archaeometry*, **45**, 33–44.
- Henderson, J., 2000, *The science and archaeology of materials: an investigation of inorganic materials*, Routledge, London.
- Hodder, I., 1982, *Symbolic and structural archaeology*, Cambridge University Press, Cambridge.
- Hodder, I., 1986, *Reading the past*, Cambridge University Press, Cambridge.
- Hosler, D., 1993, *The sound and colour of power: the sacred metallurgical technology of Ancient West Mexico*, The MIT Press, Cambridge, Massachusetts.
- Ingold, T., 2001, From complementarity to obviation: on dissolving the boundaries between social and biological anthropology, archaeology and psychology, in *Cycles of contingency: developmental systems and evolution* (eds. S. Oyama, P. E. Griffiths and R. D. Gray), 255–79, The MIT Press, Cambridge, Massachusetts.
- Jercher, M., Pring, A., Jones, P. G., and Raven, M. D., 1998, Rietveld X-ray diffraction and X-ray fluorescence analysis of Australian Aboriginal ochres, *Archaeometry*, **40**, 383–401.
- Jones, A., 2002a, *Archaeological theory and scientific practice*, Cambridge University Press, Cambridge.
- Jones, A., 2002b, A biography of colour: colour, material histories and personhood in Early Bronze Age Britain and Ireland, in *Colouring the past: the significance of colour in archaeological research* (eds. A. Jones and G. MacGregor), 159–74, Berg, Oxford.
- Jones, A., and MacGregor, G. (eds.), 2002, *Colouring the past: the significance of colour in archaeological research*, Berg, Oxford.
- Kilikoglou, V., Vekkinis, G., Maniatis, Y., and Day, P. M., 1998, Mechanical performance of quartz tempered ceramics: part I, strength and toughness, *Archaeometry*, **40**, 261–79.
- Kingery, D., 1996, Materials science and material culture, in *Learning from things: method and theory of material culture studies* (ed. D. Kingery), 181–204, Smithsonian Institution Press, Washington, DC.
- Kolb, C., 1989, Ceramic ecology in retrospect: a critical review of methodology and results, in *Ceramic ecology 1988: current research on ceramic materials* (ed. C. Kolb), 261–375, British Archaeological Reports, Oxford.
- Latour, B., 1993, *We have never been modern*, Harvard University Press, Cambridge, Massachusetts.
- Latour, B., 1999, *Pandora's hope: essays on the reality of science studies*, Harvard University Press, Cambridge, Massachusetts.
- Leach, E., 1973, Concluding address, in *The explanation of culture change* (ed. C. Renfrew), 761–71, Duckworth, London.
- Lemonnier, P., 1992, *Elements for an anthropology of technology*, Anthropological Papers No. 88, Museum of Anthropology, University of Michigan, Ann Arbor, Michigan.
- Lemonnier, P., 1993, Introduction, in *Technological choices: transformations in material culture since the Neolithic* (ed. P. Lemonnier), Routledge, London.
- Matson, F. R., 1965, Ceramic ecology: an approach to the early cultures of the Near East, in *Ceramics and Man* (ed. F. R. Matson), 202–17, Aldine, Chicago.
- Miller, D., 1987, *Material culture and mass consumption*, Blackwell, Oxford.
- Miller, D., 1994, Artefacts and the meaning of things, in *The companion encyclopedia of anthropology* (ed. T. Ingold), 396–419, Routledge, London.
- Nir-EI, Y., and Broshi, M., 1996, The black ink of the Dead Sea Scrolls, *Archaeometry*, **38**, 97–103.
- O'Connor, T., 1991, Science, evidential archaeology, and the new scholasticism, *Scottish Archaeological Review*, **8**, 1–7.
- Parker-Pearson, M., 1999, *The archaeology of death and burial*, Sutton, Stroud.
- Peacock, D. P., 1969a, Neolithic pottery production in Cornwall, *Antiquity*, **139**, 145–9.
- Peacock, D. P., 1969b, A contribution to the study of Glastonbury ware from south-western Britain, *Antiquaries Journal*, **49**, 41–61.
- Peacock, D. P., 1982, *Pottery in the Roman world: an ethnoarchaeological approach*, Longman, London.

- Palmer, J. W., Hollander, M. G., Rogers, P. S. Z., Benjamin, T. M., Duffy, C. J., Lambert, J. B., and Brown, J. A., 1998, Pre-Columbian metallurgy: technology, manufacture and microprobe analysis of copper bells from the Greater South West, *Archaeometry*, **40**, 361–82.
- Pickering, A., 1995, *The mangle of practice: time, agency and science*, Chicago University Press, Chicago.
- Pollard, A. M., and Heron, C., 1996, *Archaeological chemistry*, Royal Society of Chemistry Paperbacks, Cambridge.
- Pomiès, M. P., Menu, M., and Vignaud, C., 1999, Red Palaeolithic pigments: natural hematite or heated goethite? *Archaeometry*, **41**, 275–85.
- Prown, J. D., 1996, Material/culture: can the farmer and the cowman still be friends? in *Learning from things: method and theory of material culture studies* (ed. D. Kingery), 19–31, Smithsonian Institution Press, Washington, DC.
- Rehren, Th., 2001, Aspects of the production of cobalt-blue glass in Egypt, *Archaeometry*, **43**, 483–90.
- Rosalie David, A., Edwards, H. G. M., Farwell, D. W., and de Faria, D. L. A., 2001, Raman spectroscopic analysis of ancient Egyptian pigments, *Archaeometry*, **43**, 461–74.
- Saunders, N. J., 1998, Stealers of light, traders in brilliance: Amerindian metaphysics in the mirror of conquest, *RES: Anthropology and Aesthetics*, **33**(1), 225–52.
- Saunders, N. J., 1999, Biographies of brilliance: pearls, transformations of matter and being c. AD 1492, *World Archaeology*, **31**(2), 243–57.
- Saunders, N. J., 2002, The colours of light: materiality and chromatic colours of the Americas, in *Colouring the past: the significance of colour in archaeological research* (eds. A. Jones and G. MacGregor), 209–26, Berg, Oxford.
- Schiffer, M. B., 1996, Some relationships between behavioural and evolutionary archaeologies, *American Antiquity*, **61**, 643–62.
- Sheridan, A., and Davis, M., 1998, The Welsh ‘jet set’ in prehistory: a case of keeping up with the Joneses? in *Pre-historic ritual and religion* (eds. A. Gibson and D. Simpson), 148–63, Sutton, Stroud.
- Sheridan, A., and Davis, M., 2002, Investigating jet and jet-like artefacts from prehistoric Scotland: the National Museums of Scotland project, *Antiquity*, **76**, 812–25.
- Shortland, A. J., 2000, *Vitreous materials at Armana*, BAR International Series 287, Archaeopress, Oxford.
- Shortland, A. J., 2002, The use and origins of antimonate colorants in Early Egyptian glass, *Archaeometry*, **44**, 517–30.
- Shortland, A. J., and Tite, M. S., 2000, Raw materials of glass from Armana and implications for the origins of Egyptian glass, *Archaeometry*, **42**, 141–51.
- Sillar, B., 2001, Reply to comments on ‘Technological choices in ceramic production’, *Archaeometry*, **43**, 288–92.
- Sillar, B., and Tite, M. S., 2000, The challenge of technological choices for materials science approaches in archaeology, *Archaeometry*, **42**, 2–20.
- Thomas, J., 1990, Silent running: the ills of environmental archaeology, *Scottish Archaeological Review*, **7**, 2–7.
- Thomas, J., 2000, The identity of place in Neolithic Britain: examples from south-west Scotland, in *Neolithic Orkney in its European context* (ed. A. Ritchie), 79–87, McDonald Institute for Archaeological Research Monograph Series, Cambridge.
- Tilley, C., 1991, *Material culture and text: the art of ambiguity*, Routledge, London.
- Tilley, C., 1993, *Interpretative archaeology*, Berg, Oxford.
- Tilley, C., 1999, *Metaphor and material culture*, Blackwell, Oxford.
- Tilley, C., 2002, Metaphor, materiality and interpretation, in *The material culture reader* (ed. V. Buchli), 23–6, Berg, Oxford.
- Tite, M. S., 1972, *Methods of physical examination in archaeology*, Seminar Press, London.
- Tite, M. S., 1987, Characterisation of early vitreous materials, *Archaeometry*, **29**, 21–34.
- Tite, M. S., 1999, Pottery production, distribution and consumption—the contribution of the physical sciences, *Journal of Archaeological Method and Theory*, **6**, 181–233.
- Tite, M. S., and Bimson, M., 1986, Faience: an investigation of the microstructures associated with the different methods of glazing, *Archaeometry*, **28**, 69–78.
- Tite, M. S., and Shortland, A. J., 2003, Production technology for copper and cobalt-blue vitreous materials from the New Kingdom site of Armana—a reappraisal, *Archaeometry*, **45**, 285–312.
- Tite, M. S., Kilikoglou, V., and Veknis, G., 2001, Strength, toughness and thermal shock resistance of ancient ceramics, and their influence on technological choice, *Archaeometry*, **43**, 301–24.
- Vandiver, P. B., 1983, Egyptian faience technology: appendix A, in *Ancient Egyptian faience: an analytical survey of Egyptian faience from Predynastic to Roman times* (eds. A. Kaczmarczyk and R. E. M. Hedges), A1–144, Aris and Phillips, Warminster.