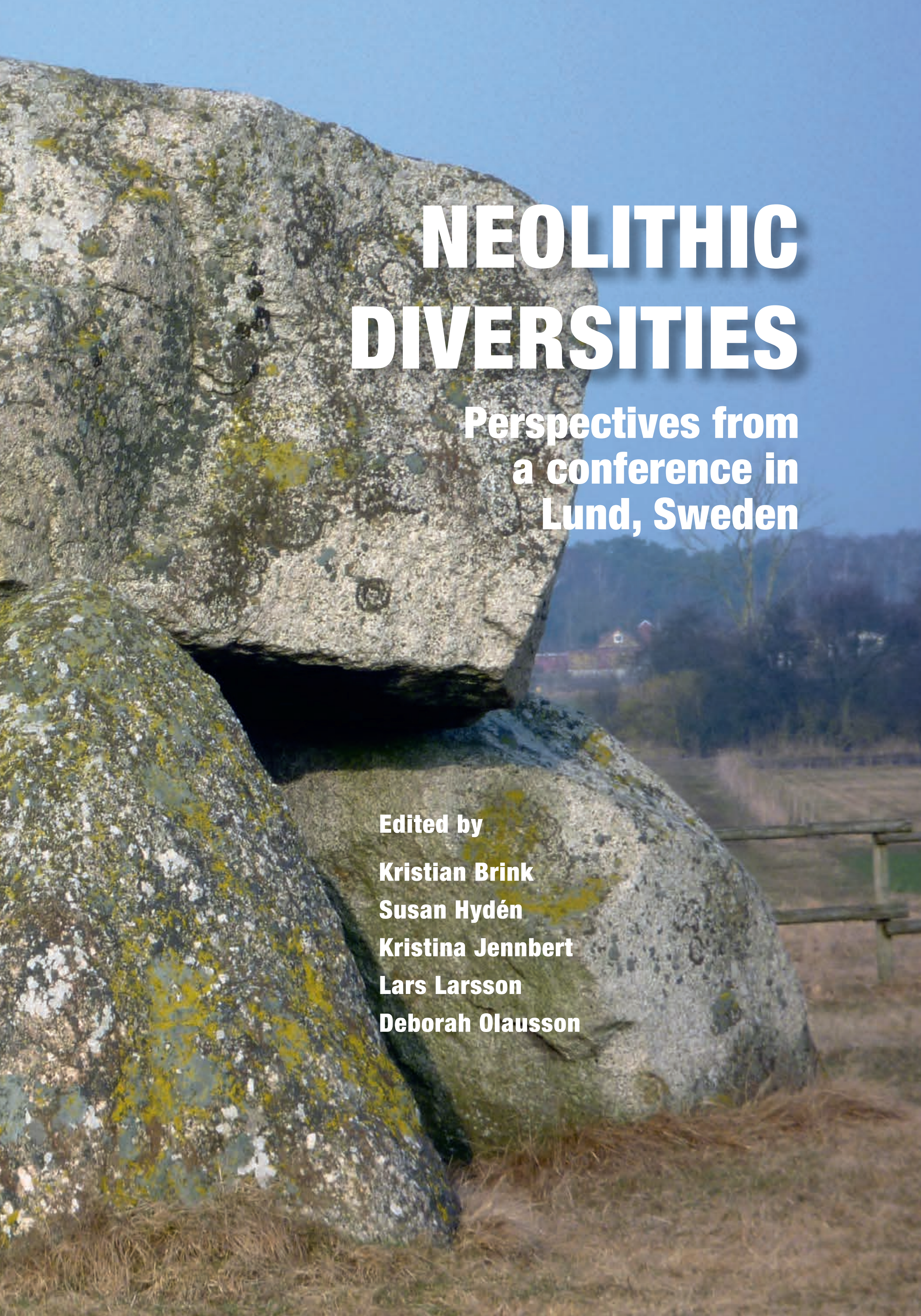

NEOLITHIC DIVERSITIES

Perspectives from a conference in Lund, Sweden

Edited by

Kristian Brink
Susan Hydén
Kristina Jennbert
Lars Larsson
Deborah Olausson

The members of the conference “What’s New in the Neolithic”, May 2013. Photo by Kristina Jennbert.

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Neolithic Diversities

Perspectives from a conference in Lund, Sweden

Editors:
Kristian Brink, Susan Hydén,
Kristina Jennbert, Lars Larsson & Deborah Olausson

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Preface

In the study of the distant human past, certain events and periods have come to represent decisive passages from one human state to another. From a global perspective, the characteristic feature of the last ten thousand years is that people in different parts of the world, and at different points in time, started to grow plants and domesticate animals. The rise and dissemination of agriculture were crucial factors for the continued existence of humankind on earth. The incipient agriculture is often regarded as the very beginning of human *culture*, as it has traditionally been perceived in western historiography, that is, as control over nature and the "cultivation" of intellectual abilities.

As a result of the increasing national and international interest in the northern European Neolithic (4000–2000 BC), combined with large-scale archaeological excavations which helped to nuance and modify the picture of the period, senior researchers and research students formed a Neolithic group in 2010. The Department of Archaeology and Ancient History at Lund University served as the base, but the group also included collaborators from Linnaeus University and Södertörn University, and from the Southern Contract Archaeology Division of the National Heritage Board in Lund and Sydsvensk Arkeologi in Malmö and Kristianstad.

Meetings and excursions in the following two years resulted in the holding of an international conference in Lund in May 2013 entitled "What's New in the Neolithic". Invitations to this conference were sent to two dozen prominent Neolithic scholars from northern and central Europe.

The conference was a great success, with presentations and discussions of different aspects of innovative research on the Neolithic. The members of the Neolithic group took an active part in the discussions following the presentations.

It was decided before the conference that the papers would be published. The members of the Neolithic group also had the opportunity to contribute current research to this publication.

After the conference an editorial group was set up, consisting of Dr Kristian Brink, PhD student Susan Hydén, Professor Kristina Jennbert, Professor Lars Larsson and Professor Deborah Olausson.

A grant was received from Riksbankens Jubileumsfond for the meetings and excursions of the Neolithic group 2010–2013. We would like to thank The Royal Swedish Academy of Letters, History and Antiquities and Berit Wallenbergs Stiftelse for grants which enabled us to hold the conference "What's New in the Neolithic". Grants from The Royal Swedish Academy of Letters, History and Antiquities, and Stiftelsen Elisabeth Rausings Minnesfond financed the layout and printing of this publication.

III. PERSPECTIVES ON MATERIAL CULTURE

An ABC of lithic arrowheads

A case study from southeastern France

Kevan Edinborough, Enrico R. Crema, Tim Kerig and Stephen Shennan

Abstract

If archaeology is to take a leading role in the social sciences, new theoretical and methodological advances emerging from the natural sciences cannot be ignored. This requires considerable retooling for archaeology as a discipline at a population scale of analysis. Such an approach is not easy to carry through, especially owing to historically contingent regional traditions; however, the knowledge gained by directly addressing these problems head-on is well worth the effort. This paper shows how population level processes driving cultural evolution can be better understood if mathematical and computational methods, often with a strong element of simulation, are applied to archaeological datasets. We use computational methods to study patterns and process of temporal variation in the frequency of cultural variants. More specifically, we will explore how lineages of lithic technologies are transmitted over time using a well-analysed and chronologically fine-grained assemblage of central European Neolithic armatures from the French Jura. We look for sharp cultural transitions in the frequency of armature types by trying to detect significant mismatches between predictions dictated by an unbiased transmission model and observed empirical data. A simple armature classification scheme based on morphology is introduced. The results have considerable implications for analysing and understanding cultural transmission pathways not only for Neolithic armatures, but also for the evolution of lithic technology more generally in different spatiotemporal contexts.

Department of Archaeology, Institute of Archaeology, University College London- 31-34 Gordon Square, London WC1H 0PY, UK (CaSES Research Group, Department of Humanities, Universitat Pomepeu, Fabra). k.edinborough@ucl.ac.uk

Department of Archaeology, Institute of Archaeology, University College London- 31-34 Gordon Square, London WC1H 0PY, UK (Department of Archaeology, University of Belgrade, Serbia). e.crema@ucl.ac.uk

Archaeology of Pre-Modern Economies (DFG Research Training Group 1878), Universities of Cologne and Bonn, Albertus-Magnus-Platz, D-50923 Cologne, Germany. tkerig@uni-koeln.de

Department of Archaeology, Institute of Archaeology, University College London- 31-34 Gordon Square, London WC1H 0PY, UK. s.shennan@ucl.ac.uk

Introduction

OVER 40 YEARS ago David Clarke in his seminal work *Models in Archaeology* suggested archaeologists should construct explicit testable models (Clarke ed. 1972), but unfortunately few European researchers do this formally with cultural questions at large regional or supra-regional analytical scales. In contrast, multi-scaled explanatory models supported by highly theorized quantitative methods are the norm in the Natural Sciences. The spectacular success of evolutionary biology is a case in point and can be attributed to two major developments. Firstly, a developed population level theoretical approach emerging last century resulting from biology's "New Synthesis" followed by a staggering series of molecular level discoveries (Gilbert *et al.* 1996). Secondly, the development of complementary analytical tools that harness the exponential growth in computational processing power has expanded the array of tools for investigating increasingly sophisticated research questions.

Our agenda is clear. If archaeology is to assume a lead role in the social sciences as opposed to simply following an agenda set by anthropology, it must undergo its own theoretical "New Synthesis". This is because developed population level thinking (Boyd and Richerson 1985) allows us to systematically analyse site and regionally-scaled consequences of aggregated technological choices which result in the innovation and spread of cultural traits and "variants".

Population thinking combined with computational modelling allows us to infer cumulative consequences of specific individual behaviours, enabling direct comparison between theoretical expectation and empirical observation. Archaeologists can benefit enormously by applying this type of formal analysis to modelling cultural transmission following Boyd and Richerson's theoretical lead (1985), as a testable narrative can be constructed that may be compared with the modelled effects of external environmental drivers of cultural variation, since expected ranges of summary statistics can be obtained and compared with other empirical evidence (Shennan 2011).

Archaeology is now ideally positioned within the social sciences to evaluate and test explanatory models of cultural transmission on a case-by-case basis, as this is the only discipline with direct access to material residues of individual decisions deposited in the cultural record over considerable periods of (sometimes) well-dated time and space. The lithic residue of ancient lithic armatures provides us with a particularly good dataset for testing the predictions of theoretical and experimental quantitative culture transmission work (Bettinger & Eerkens 1999; Edinborough 2008; Mesoudi & O'Brien 2008a & b). Here we develop a paradigmatic classification scheme and apply a simulation-based analysis to infer patterns of cultural change in a very well contextualized case-study area in western Europe. To do this we fit an unbiased transmission model (whereby the probability of adopting a given cultural trait is determined solely by its frequency in the population and the rate of cultural innovation; Boyd & Richerson 1985) to the entire sequence and determine whether specific transitions exhibit strong divergence from our expectations. First, however, we briefly examine the historical reasons why some problematical assumptions are currently made by traditional lithic armature studies.

A brief history of time's arrowheads

The ancient, ubiquitous and persistent nature of stone tools compared to many other lines of archaeological evidence provides us with an excellent opportunity to analyse mode and tempo of technological transmission with a suite of new methodological advances based on populational thinking (Shennan 2011).

In archaeology, directional sequences of technological evolution could only be speculative prior to the development of taxonomic systems-theory, coupled with relative and radiometric dating techniques. Systematic typological classification of lithics formally originated in Scandinavia, perhaps when the Swedish polymath Kilian Stobæus (1690–1742), himself a voracious collector of antiquities including many lithics, outrageously noted in 1738 that stone age axes and daggers were anthropogenic in origin, and not created by lightning as commonly believed (Per Karsten pers. comm.). The influential classification scheme of Stobæus' more famous student at Lund, Linnaeus, subsequently revolutionized the science of taxonomy. The underlying principle of Linnaeus' seminal and influential *Systema Naturae* (1735) was *typological,* he provided an essentialist taxonomy for the natural world, directly related to

Aristotelian concepts of discretely named and categorized *essences (*Hull 1965; 1981). Biology later rejected Linnaeus' immutable categorization of species and static natural ordering, supplanted in 1859 by Darwin's fluid explanatory mechanism of biological "transmutation", more commonly known as descent with modification. As Hull states, the three essentialistic tenets of typology following Aristotle are firstly, the ontological assertion that (Platonic) forms exist; secondly, the methodological assertion that the task of taxonomy as a science is to discern the essences of species; and thirdly the logical assertion concerning a definition, that is to say the classificatory type-name that designates an essence (Hull 1965, p. 317). When constructing a classificatory system archaeologists can benefit from an overt awareness of these tenets, as treating clearly variable tool types consciously or unconsciously as implicit essentialist *species* leads to a mismatch of units of analyses, technical lineages, and thus an erroneous analysis of the lithic data at hand (O'Brien & Lyman 2000).

Armature classification

Our classification scheme for Neolithic armatures explicitly looks at the trait level rather than the whole artefact unit of analysis, avoiding the typologically rooted "species problem" (Hull 1965), in an attempt to avoid the circularity of measuring interdependent technological traits (Edinborough 2008; Buchanan and Collard 2007). We use a *"paradigmatic"* or *materialist* approach, as opposed to a *typological essentialist* approach (Dunnell 1971; O'Brien & Lyman 2000), which sees types not as immutable entities like Linnaean species, but as populations of traits in a constant state of becoming (Hull 1965). It was this revolutionary switch from an essentialist to a materialist philosophy in biology that was the key theoretical advance enabling the intellectual fecundity of the biological New Synthesis (O'Brien & Lyman 2000).

As the only secure way to distinguish an arrow head from a dart head armature is the close association of a wooden shaft with a diagnostic knock end for a bow string (Rausing 1967; Edinborough 2004), armatures are identified as such by each individual lithic analyst. This is done by noting hafting polish, agreed optimal metric ranges, high or low velocity spin off fractures, or more likely a combination of these diagnostic features compared with known ethnographic analogies and experimental work (Edinborough 2008). Arrowhead identifications by different analysts presumably have some degree of error, and issues remain as to correct identification of artefact use-wear, reusage and resharpening (Knarrström 2001); although these issues are not significant in a large enough spatial-temporal sample due to the destructive nature of a relatively high velocity impact (Knarrström 2001). Arrowheads are constrained by size for functional and engineering reasons (Friss-Hansen 1990), and can metrically separate out bimodally as separate distributions from generally larger dart points (Shott 1997), although the precise measurements, methods and results involved are hotly debated among lithic analysts (Edinborough 2004; 2008; Riede & Edinborough 2012). Circumalpine wetland archaeology has its own tool-type classificatory issues that may prove problematic, as ambiguous lithic tools, i.e. potential daggers, knives, or chisels, may possibly be misclassified by a given analyst.

Despite these potentially confounding issues, we do not believe this debate makes it problematical to establish the lineages of technological descent we are interested in here, as the instances where armatures are perhaps misclassified will appear as statistical outliers and can be accounted for. It follows that our classification scheme places a greater emphasis on proximal and basal characteristics, following the work of Bettinger and Eerkens (1999), as the extant archaeological and ethnographic evidence suggests that there is considerably more variety in a projectile point basal element than the distal element, certainly prior to the later innovation of metal arrowhead mouldings (Saintot 1998).

Case study

Some scholars have applied population-level approaches towards understanding cultural transmission processes underlying armature assemblages with some success (e.g., Bettinger & Eerkens 1999; Mesoudi & O'Brien 2008a & b), whilst a general lack of armature sequences obtained from securely stratified sequences remains problematic. Finding deep-time secure temporal sequences with significant numbers of armatures is a rare occurrence. It is difficult to constrain relatively or poorly dated sequences with the necessary temporal precision required to tightly constrain explanatory models (Edinborough 2008). On the other hand, following a tradition over 150 years old, circum-alpine Neolithic lake-dwelling excavations present researchers with unprecedented stratified sequences (Pétrequin & Bailly 2004) especially since the Centre National de la Recherche Scientifique and the Sous-Direction de l'Archéologie made the lakes of Chalain and Clairvaux focused case-studies for French prehistory, with an intensive research programme instigated by Pétrequin (e.g., 1998). In particular, the sites on the shores of these lakes in the Jura region of southeastern France have an excellent chronology associated with a highly detailed study of lithic armatures ideal for testing competing theories of cultural change (Pétrequin 1993; 1998; Saintot 1998).

A series of cultural historical interpretations of these sites have been supported by various analyses of material culture arcing across southeastern France. A dynamic cultural milieu emerges, characterized by variation in technological and stylistic traditions (Pétrequin 1998; Saintot 1998; Shennan 2000). A comparison of the environmental pollen record with breaks in the settlement sequence and variation in different cultural assemblages (Pétrequin 1998) has shown clear support for models of abrupt cultural replacement in the French Jura region, notably in the appearance of the Horgen culture early in the 32nd century BC, followed by the transition to Ferrières cultural assemblage, thought to intrude from the south, in the late 31st century BC. The development of the local Clairvaux culture then follows, down to *c.* 2750 BC. From 2750 to 2400 BC armature morphology diversifies and this is thought to be an indigenous development influenced by greater trade networks in the context of the local Chalain culture. The transition to the Bronze Age is perhaps not so clear-cut, with competing models of cultural replacement and gradual change (Pétrequin 1998; Shennan 2000). The subsequent standardization of arrows on barbed and tanged types indicates Bell Beaker influences from 2400 BC that carry on to the Middle Bronze Age in that particular area (Saintot 1998).

The original armature analysis by Saintot (1998) was based on defining 34 elementary morphological types, aggregated into 17 types, from 280 securely identified arrowheads out of a total of 408 armature lithics, whose trajectories through time were characterized on the basis of their changing frequencies (Saintot 1998, Figs. 38–40). Saintot concluded that the patterns of morphological variation she identified in the different types of armatures could be ascribed to a number of cultural processes relating to changes in the direction of the cultural affiliations evidenced in the artefact assemblages from the sites concerned. These resulted from regional scale demographic movements and changing exchange links. Saintot used 9 chronological phases (I: 3700–3600 BCE; II: 3450 BCE; III: 3200 IV: 3100 BC; V: 3050–3010 BCE; VI: 3010–2930 BCE; VII: 2850–2750

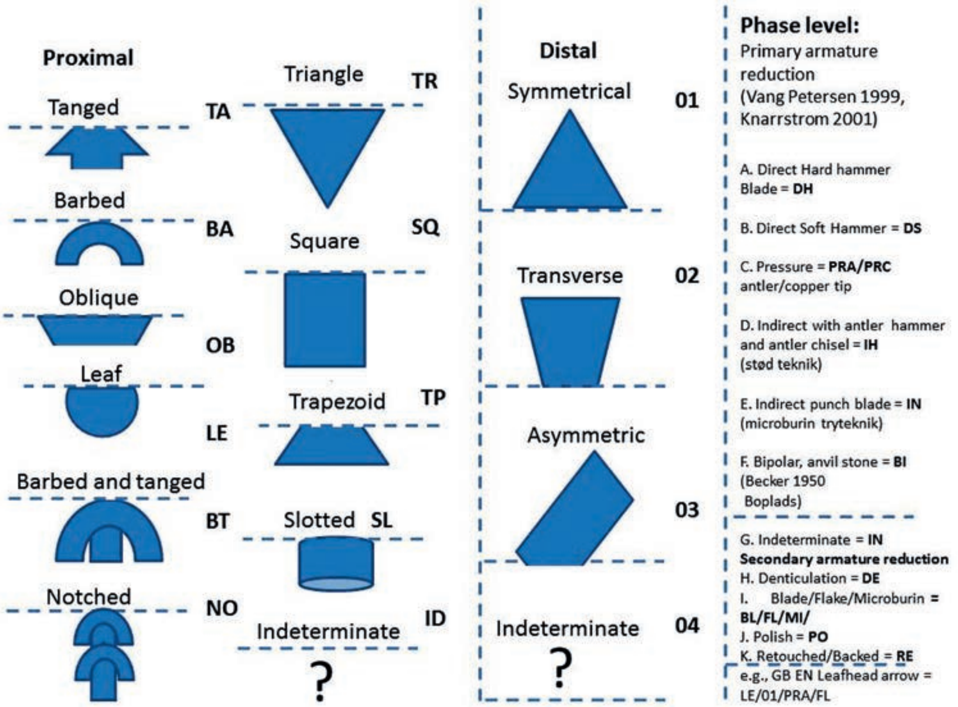


Fig. 1. Attributes used to define the paradigmatic classification for armature traits based on key morphological characteristics. Note the focus on capturing the greater variation present at the proximal end of the armature, which is often hidden when attached to an arrowshaft by mastic and binding technology (cf. Edinborough 2004).

BCE; VIII: 2750–2600; IX: 2600–1650 BCE), following Pétrequin (1998), although the first two were very poorly represented (only 5 arrowheads), and identified two particular periods of change affecting not just armatures but also pottery and ornaments, the first *c.* 3200 BCE, marked by incoming communities from the east entering into contact with areas to the south and the second with the appearance of Bell Beaker material at *c.* 2500 BCE (Saintot 1998, p. 207).

Our study and classification scheme differs from that of Saintot (1998) in two fundamental ways. First, in contrast to her type construction we use as the basic type unit unique combinations of traits identified by our paradigmatic classification. The attributes used to construct the types and the types themselves are shown in fig 1. The attribute values were derived from the armature illustrations in plates 24–43 of Saintot cross referenced against the tables of data therein, and from previous ethno-archaeological research which indicates that the proximal end of lithic arrowheads contains the most variability and is therefore useful for measuring cultural and technological variation (Edinborough 2004; Saintot 1998).

Second, our aim is not to relate the types to the broader cultural context of the sites, the main focus of Saintot's discussion, but to fit evolutionary models of social learning and to address the question of whether any of the phase transitions showed a more marked change than predicted by the model. There are too few armatures present in phase II to investigate the phase II-III transition argued by Saintot to represent the earliest major change in the local sequence. The other predicted significant

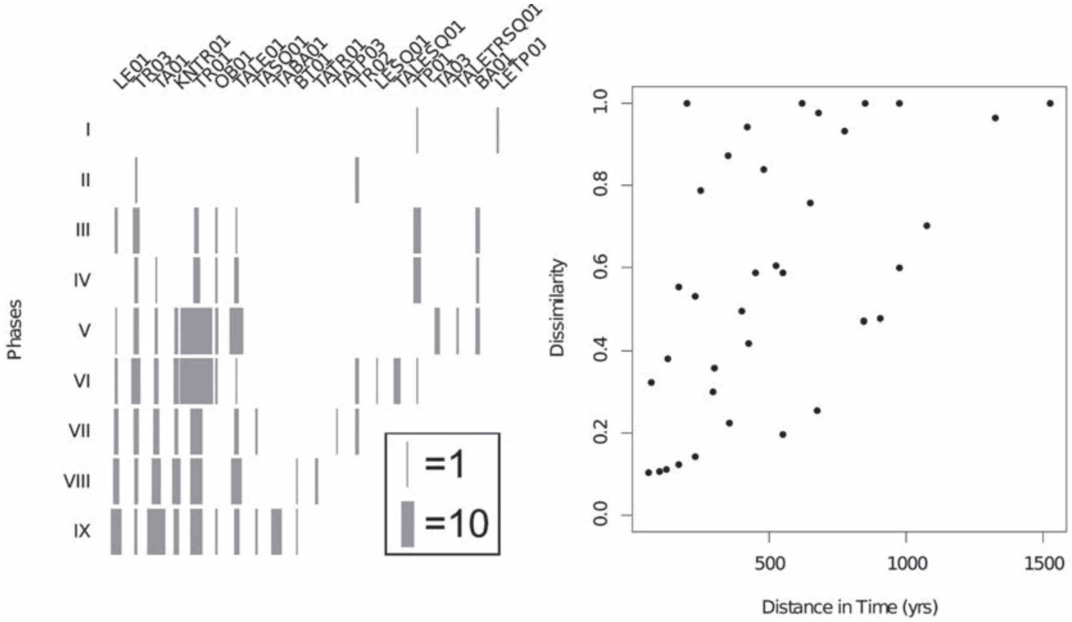


Fig. 2. The relative frequency of our armature types in each archaeological phase (left plot), and Morisita-Horn dissimilarity against temporal distance (right plot) measured between the mid-points of each phase of all pairs of phases identified at the Clairvaux-Chalain sites.

change is that associated with the appearance of Bell Beakers though it is ambiguous from Saintot whether this is represented by the phase VII–VIII or VIII–IX transition.

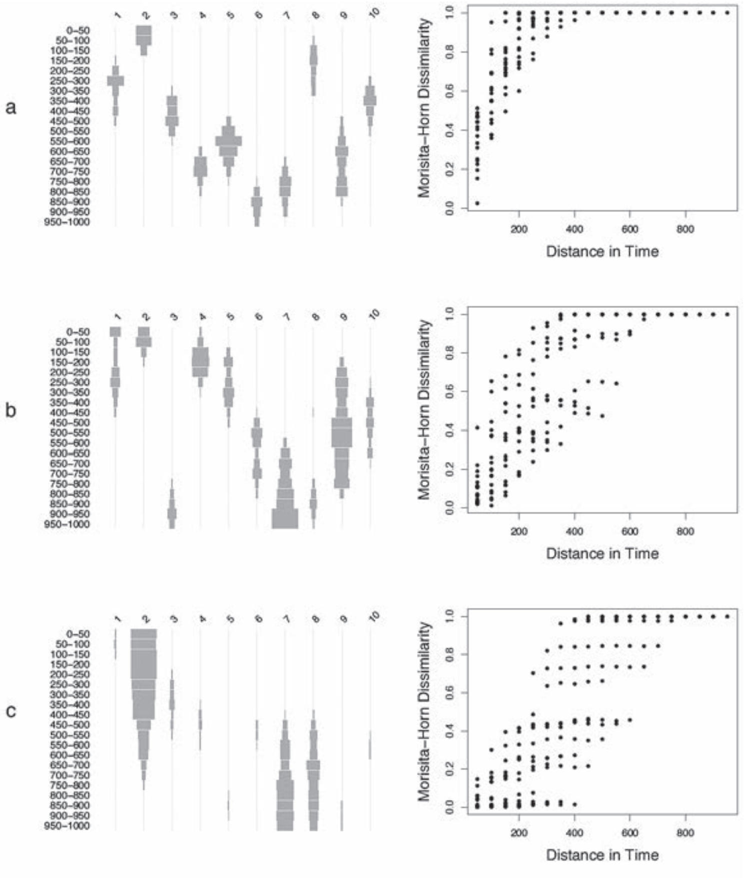
Temporal changes in the frequency of artefact types offer the possibility for examining, inferring, and testing models of cultural transmission (Neiman 1995; Shennan & Wilkinson 2001; Kandler & Shennan 2013). Mathematical models originally developed in evolutionary biology, and modified to incorporate dynamics intrinsic to cultural transmission (Boyd and Richerson 1985), allow us to make explicit quantitative predictions of population level summary statistics that can be tested against the observed record.

Given that our objective is to examine potential variations in the evolutionary process over time, we chose as a summary statistic of our data the dissimilarity in the frequency of artefact traits between all possible pairs of cultural phases. We use the Morisita-Horn dissimilarity statistic (Morisita 1959; Horn 1966), an ecological index that quantifies the compositional dissimilarity between two vectors of frequency, ranging from 0 (identical composition) to 1 (complete absence of shared types).

The scatterplot in fig. 2 shows a significant correlation between the two measures as expected (R^2 =0.319, p-value= 0.024, Mantel Test with 1,000 permutations), as the longer the temporal distance between two phases, the higher the dissimilarity in the frequencies of different armature types. On the other hand, the scatterplot also shows a variation in the dissimilarity between phases at approximately the same interval. Can we safely state that these differences are resulting from different generative cultural transmission processes, or are these levels of diversity to be expected from the same process? Can we safely ignore the effect of sample size or time-averaging (e.g. Premo 2014)?

Here we use Approximate Bayesian Computation (ABC, Beaumont *et al.* 2002; see Crema

Fig. 3. Simulation output of frequency change in cultural traits (left column) and corresponding scatter plot of Morisita-Horn dissimilarity vs. time distance. Simulation generated from an unbiased transmission model, with a population size of 500 and innovation rates of 0.01 (a), 0.005 (b), and 0.001 (c). The frequencies depicts the 10 most common traits from each simulation.



et al. 2014 for an archaeologically tailored discussion on the method as well as methodological discussion of the present case study), a computational method that enables us to infer, for a given simulation model, the parameter values that will provide the best fit to an observed dataset. This is achieved by iteratively generating artificial summary statistics (comparable to the observed ones) using different parameter values sampled from a prior parameter distribution. The final output of ABC is a probabilistic estimate of the parameters values that is informed both by the hypothesized model and the empirical data.

We used the dissimilarities plotted on fig. 2 as our empirical data-set and assumed that if the generative process behind the empirical record was unchanging, differences in the dissimilarity indices between the observed and simulated data should be small and randomly distributed. Consequently, any changes in the generative process (e.g. an increase in the innovation rate, transmission mechanism, population size) should lead to significant deviations at key transitions (as those expected from phases VII–VIII and/or VIII–IX).

Unbiased Cultural Transmission

One of the most commonly adopted models for exploring the frequency of different artefact types is the unbiased transmission or random drift model (Boyd and Richerson 1985; Bentley *et al.* 2004). The key principle is that the most parsimonious initial assumption in the pattern of cultural transmission is a neutral

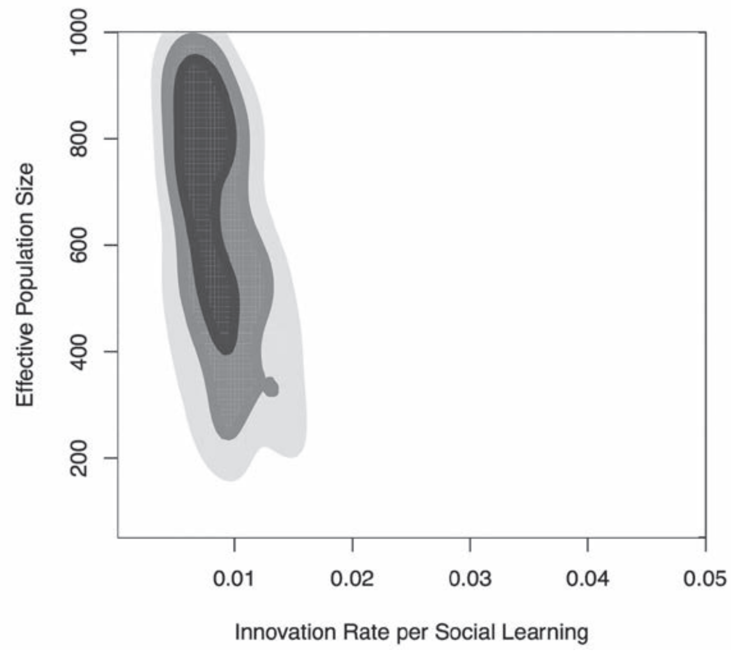


Fig. 4. Posterior density distribution of the two simulation parameters obtained from ABC.

process where selective biases are absent. In other words, the likelihood of copying a cultural trait is purely a function of how frequent this trait is. Under this model, two variables play a pivotal role in defining the dynamics of cultural evolution: the rate of innovation and the effective population size. The former is simply the frequency by which a new cultural trait is invented within defined interval of time *t*. The invention is at the individual level and does not necessarily imply the adoption of the trait by all other individuals. The effective population size can be conceptualized in different ways, from the number of social learners to the observed sample that play a role in the copying process. It is important to stress that the effective population is not equivalent to the actual population size, although a positive correlation between the two can be expected.

Fig. 3 shows how variation in the innovation rate alone can generate different patterns under the same unbiased cultural transmission process, though all of them bear a strong resemblance to classic archaeological "battleship curves". When innovation rate is high (Fig. 3-a), variants have a shorter time-span of existence. Consequently if we plot the dissimilarity against distance in time (as we did in Fig. 2) we have a steep curve, suggesting a fast rate of cultural evolution. When the rate of innovation is low (Fig. 3-c), cultural variants have a longer persistence over time, and the scatter plot exhibits a shallower curve. Thus depending on the rate of innovation we should expect different levels of dissimilarity between two archaeological phases at the same temporal inter-distance. Fig. 3 also highlights how the very same model and parameters can generate, as a consequence of the random nature of the copying process, a range of dissimilarity values for the same temporal distance.

Fitting the model and detecting outliers

The variation observed in fig. 3 indicates that given a temporal distance between archaeological phases we might expect a variety of values in the dissimilarity measure depending on the choice of our model parameters. This leads to the question of how we can evaluate episodes of significant change at Clairvaux-Chalain, if we do not know what exactly we should expect. In other words, if the process generating the

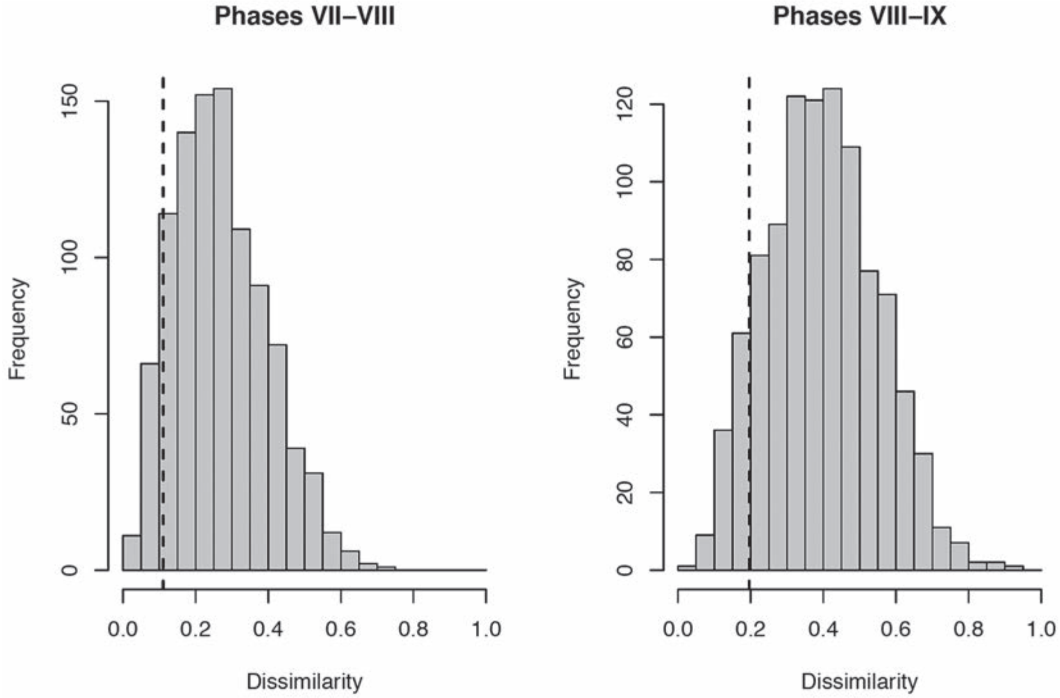


Fig. 5. Dissimilarity ranges expected from the unbiased transmission compared to observed values (dashed line) for phases VII to VIII and VIII to IX.

pattern observed in the frequency changes of arrowhead typology was unbiased transmission, what were the innovation rate and the effective population size?

Fig. 4 shows the parameter estimates of the unbiased transmission model obtained from ABC. Assuming that individuals can socially learn approximately once a decade (for bow-arrow technology see Hill & Hurtado 1996), the simulation shows that the best-fit model has an innovation rate of approximately 0.01 (equivalent to an innovation per 1000 years per person), and an effective population size between 200 and 1000. It is worth noting that these parameter estimates are functions of the assumptions built into the model (i.e. frequency of transmission events), and hence their interpretation should be cautious, and restricted to relative terms, rather than absolute ones. However, a more conservative approach using bootstrapped summary statistics and a probabilistic range (rather than a fixed value) for the frequency of transmission events yielded similar results (see Crema *et al.* 2014), suggesting that the overall conclusion of the study is sufficiently robust.

The posterior estimates of the model parameter obtained from ABC enable us to estimate expected dissimilarity for any given pair of archaeological phases, taking into consideration sample size, time-averaging, temporal distance between the two assemblages, and the inferred innovation rate and effective population size. Fig. 5 shows such expected dissimilarity values for the transitions of our interest (phases VII to VIII and VIII to IX), which can be compared against the observed dissimilarity (shown as a vertical dashed line). This strongly suggests that the observed dissimilarity is lower than that expected by the unbiased transmission model. Such a result is the opposite of what would be expected if there was a major cultural change during this interval, despite the later appearance in phases VII–VIII and VIII–IX of distinctive barbed and tanged arrowhead morphologies, often intuitively associated with the dramatic arrival of Bell Beaker culture or perhaps even Horgen dagger technology (Furestier 2007; Vander Linden 2006).

Conclusions

This paper shows how population level processes driving cultural evolution can be better understood if mathematical and computational methods, often with a strong element of simulation, are applied to archaeological datasets. We navigate through persistent previous taxonomic problems archaeologists inherited from other disciplines long ago by adopting a population-based approach, coupled with a trait-based paradigmatic taxonomic classification scheme for armatures and a statistical method that enabled us to formulate our hypothesis as a simulation model.

We conclude that our population level approach uses new computer-based Bayesian methods that make it possible to generate simulation models integrating theory with archaeological evidence to compare outcomes with observed data. This approach has great utility for studying armature evolution across European research traditions. Our approach is tailor-made for exploring highly specific models of cultural transmission elsewhere in the archaeological record so we believe the implications for better understanding other technological lineages with this methodology are profound. We hope this new approach and others like it will enable archaeology to undergo its own much needed New Synthesis.

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