interpreting lithic raw material variability in Middle Palaeolithic contexts: a modeling approach with applications to the Bau de l'Aubesier (Southeastern France)

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Chapter Six
Conclusions

1 Overview

Mobility is a critical variable underpinning hominin adaptation (e.g., Kuhn, 2020, and references therein). Despite the increasing availability of novel approaches to inferring aspects of human mobility in the Middle Palaeolithic, including stable isotope analyses (e.g., Richards et al., 2008; Moncel et al., 2019; Nava et al., 2020) and insights from energetics and biomechanics (e.g., Verpoorte, 2006; Henry et al., 2017), lithic raw materials are likely to continue supplying the bulk of essential information for the foreseeable future. In this regard, evidence of toolstone transfer across the landscape is widely thought to be informative with respect to the sizes of the territories regularly exploited by human groups at different scales (e.g., daily foraging areas, areas habitually used in the context of residential mobility, Gamble's [1999] 'landscapes of habit'), and of the land-use strategies such groups employed within those territories (e.g., Frahm et al., 2016; Turq et al., 2017; Kuhn, 2020). Beyond this, provenance data is needed in order to evaluate lithic raw material exploitation in light of its environmental availability and accessibility. This, in turn, provides critical information on how stone, the only resource exploited throughout the entire history of our genus for which evidence of use survives in a relatively unaltered state at the vast majority of prehistoric sites, was conceptualized, selected, and managed in the past.

While lithic provenance data is thus essential for understanding important aspects of our evolutionary history, interpreting them in terms of past behaviours is a difficult task. Unfortunately, the attention devoted to this task has not been commensurate with its significance, and we continue to be constrained by interpretive frameworks developed decades ago, at the dawn of provenance studies (see Chapter 1). Partly as a consequence of this, the present consensus view of Middle Palaeolithic raw material exploitation is rather monotonous and not dramatically changed since the 1980s, with a localized exploitation of lithic resources and a general lack of evidence for inter-group exchange being its main features across much of the Neanderthal range. To be sure, our understanding is now more nuanced (see, for example, Feblot-Augustins, 2009; Meignen, 2009) but, tellingly, few formal approaches have been proposed to investigate the intricacies of local source selection – the most salient aspect of Middle Palaeolithic toolstone procurement - in detail (e.g., Browne and Wilson, 2011; Frahm et al., 2016; Wilson et al., 2018). Rather than refining long-established frameworks through, for instance, more realistic methods of quantifying key variables (e.g., considering terrain when computing access costs), what may be needed instead is a rethinking of the questions we ask of the data, and of the methods we use to look for the answers.

As argued in Chapter 1, part of the reason why it has been difficult to move beyond the earliest interpretive frameworks is the under-reporting of basic provenance data and the often-uncritical use of key terminology. Progress has also been hampered by the subservient role provenance studies typically have within research agendas whose primary focus is on explaining lithic techno-typological variability – indeed, some have argued that sourcing can *only* be "relevant when integrated with a technological study" (Tomasso and Porraz, 2016). I do not dispute the importance of integrating provenance data with other lines of evidence in order to provide a fuller, more realistic picture of the past, but I argue that

such integration should occur after toolstone procurement has been understood in its own terms. Consequently, this thesis has been an attempt to enable provenance data to provide, insofar as possible, their own, independent account of the past. My goal here has been to lay the foundation for an alternative approach to interpreting such data that can allow us to fully explore its intrinsic potential.

To this end, I began this project by undertaking the first systematic re-evaluation of a neutral, agent-based model of raw material procurement originally proposed by Jeffrey Brantingham in 2003. The model offered a point of departure that stood in stark contrast to traditional approaches, since it aimed to explore what raw material variability should look like under conditions of no optimization in toolstone procurement and on the basis of a minimalist set of assumptions. Computer simulations of the kind proposed by Brantingham (2003) seemed particularly promising because they are not inherently limited by the quality of archaeological provenance datasets, because they require explicit and formal definitions for all modelled behaviours and parameters, and because they are theoretically capable of generating hypotheses which can be unambiguously rejected on the basis of empirical observations. On the other hand, Brantingham's interpretation of qualitative similarities between model-generated and archaeologically observed patterns seemed unconvincing. As detailed in Chapter 3, my reassessment of the model revealed that its original implementation was indeed flawed, and so were some of Brantingham's interpretations. In Chapter 3 I therefore introduced a revised model and laid out a new set of expectations for lithic discard records generated under neutral behavioural conditions. Importantly, my reassessment also revealed a danger inherent in building neutral models of complex phenomena, namely the very concrete risk of unwittingly simulating impossible realities due to excessive abstraction, and the difficulties of evaluating whether this may have been the case.

Based on these insights, I sought to develop a minimally realistic simulation approach using real archaeological data from the Bau de l'Aubesier (hereinafter, "the Bau" - see Chapter 2), a French Middle Palaeolithic site chosen due to the availability of an excellent and well-published provenance dataset, and evidence of raw material exploitation that clearly deviates from revised neutral expectations. My goal was, after all, to develop an approach that could reveal meaningful aspects of past land and resource use beyond a simple confirmation (or rejection) of a null model (cf. Oestmo et al., 2020). As a critical step towards this goal, Chapter 4 introduced a new approach to generating and testing hypotheses of landscape knowledge, navigational abilities, and local resource selection criteria reflected in provenance data, one which, importantly, did not rely on other lines of evidence (e.g., ethnographic analogy). Beyond offering a simple and elegant explanation for the entirety of the Bau data, including the avoidance of a majority of sources available in the region over a period of roughly 100,000 years, my results provided essential information for developing a sound and well-calibrated minimally realistic agent-based model that is spatially and temporally explicit. In doing so it also addressed, albeit from a different perspective, important issues raised in Chapter 3 regarding a) the importance and conceptualizations of lithic resources in the past, b) the need to incorporate the spatial configuration of sources in our explanatory frameworks, and c) the need to consider unused resources as well, since, contrary to Brantingham's (2003) assertion, *all* resources within a given radius of a site should be used under neutral assumptions.

I proposed, implemented, and applied one such model in Chapter 5. This model addressed the challenge pointed out in Chapter 3 regarding parameter calibration and delivered on the promise of enabling precise quantitative predictions of archaeologically observable variability. My model's primary aim was to explore the effects of regional-scale mobility on observed raw material variability in view of further

testing insights from Chapters 3 and 4. The model simulated and tracked the utilization of lithic raw materials throughout their use lives employing real units (i.e., grams of stone), thus allowing for a careful consideration of different pathways through which lithics may be incorporated into discard records. My analyses indicated that data available from the Bau are incompatible with the settlement of relatively large areas of the study region by hominins who a) also resided at the Bau and b) selected lithic resources according to broadly similar criteria to those evidenced at the site. Settlement of other, similarly large areas, however, are compatible with archaeological observations at the study site. Importantly, predictive maps generated on this basis, such as the one presented in Chapter 5, can be validated with empirical observations in a straightforward manner: a contemporaneous site located in an area of low compatibility should evidence different resource selection criteria than those seen at the Bau, while contemporaneous sites showing similar selection criteria should be located in high compatibility zones.

Aside from this insight into regional land use and a confirmation of the overall conclusions presented in Chapter 4, my analyses of the minimally realistic model also revealed that at many sites we may expect to find a non-negligible influx of materials collected while residing elsewhere and transported within mobile toolkits. Importantly, a substantial proportion of such materials (under modelled conditions, ca. 50%) may originate from sources that are also locally exploited. This has two major implications: on the one hand it suggests we may be underestimating the contribution of imported materials at many sites (e.g., if 15% of materials appear to be 'non-local', imported materials may account for 30% of an assemblage), and consequently the degree of mobility such assemblages may represent, and on the other it complicates the interpretation of raw material types that are represented at all stages of lithic reduction as locally procured (see also Turq et al., 2013).

2 Addressed research questions

Overall, the framework developed in Chapters 3-5 and briefly summarized above enabled me to answer the research questions presented in Chapter 1, as outlined below.

2.1 Neutral models as alternative, value-free starting points

Neutral agent-based models are useful points of departure for developing interpretive frameworks that minimize assumptions and maximize interpretive potential. Indeed, my re-evaluation of Brantingham's (2003) model led to critical insights that enabled me to develop the resource selection model presented in Chapter 4 and the minimally realistic model implemented in Chapter 5. These insights include the need to: a) consider all sources of usable materials available in an area, not just exploited ones; b) consider the spatial configuration of all sources in evaluating likelihoods of exploitation for any given one; c) explicitly focus on discard records instead of toolkits and, more generally, to d) avoid excessive abstraction and pursue instead a minimal degree of realism; e) to evaluate the degree to which lithic resources may have been essential to survival; and f) make quantitative predictions regarding archaeological raw material variability.

2.2 Areal extent of local resource exploitation in the Middle Palaeolithic

Provenance data available from the Bau de l'Aubesier suggest Middle Palaeolithic hominins regularly exploited resources reachable within 2.5 to 3.5 hours from home bases (Chapter 4), scheduling lithic procurement within other primary activities. It is possible that this 'foraging radius' may have been

somewhat smaller (Chapter 5), but the available evidence provides no support for the view that Neanderthals regularly exploited lithic resources over a smaller extent than typically documented with ethnographic hunter-gatherer populations (Chapter 5). These results challenge aspects of the prevailing view on Middle Palaeolithic procurement, and suggest the latter may be in part a consequence of compiling and analyzing provenance data within interpretive frameworks that are poorly suited to the purpose.

2.3 Neanderthal home ranges

Raw material provenance data is likely uninformative with respect to the home ranges of Neanderthal groups, maximum transfer distances most likely reflecting instead the extent of combined territories utilized by individuals who at some point also resided at a site. Raw material frequencies therefore do seem to reflect the scale of adaptation (e.g., Binford, 1979), but not in a straightforward manner. Based on the results of Chapter 5 and insights derived from Chapter 3 and 4, I suggest that, to understand land use on the basis of archaeological raw material variability, we should model zones of compatibility with empirical observations using computer simulations rather than considering raw material transfer distances and directions. In the area surrounding the Bau de l'Aubesier, such zone of compatibility extends over only parts of the study region (ca. 1708 km^2 have estimated compatibility values greater than 50%).

2.4 Neanderthal conceptualizations of space and lithic resources

The evidence available from the Bau de l'Aubesier is most consistent with a strictly utilitarian and pragmatic use of lithic resources (Chapter 4). None of the analyses conducted in Chapters 4 and 5, however, lends support to one of the implicit assumptions of the neutral model re-evaluated in Chapter 3, namely that lithics may not have been essential for the survival of the site's residents. Consequently, and as underscored by the results presented in Chapter 5, concluding that lithic assemblage richness is, by itself, a very poor predictor of occupational histories (Chapter 3) is likely overly pessimistic.

Notwithstanding the strictly utilitarian use of stone, provenance data available from the Bau de l'Aubesier also indicate a high degree of selectivity, manifested in the consistent targeting of optimal or quasi-optimal procurement alternatives. As noted in Chapter 1, stone is a predictable resource, and as a consequence optimal sources can become known over time, eventually entering collective memory (see, e.g., Raynal et al., 2012). As shown in Chapter 4, however, the spatial knowledge of Neanderthals at the Bau amounted to more than simple awareness of the location of such optimal sources, as they appear to have been able to accurately calculate access costs to these from arbitrary locations on the landscape, which in turn suggests an ability to use Euclidean mental representations of space.

3 Other contributions of this work

The process of developing and implementing my proposed framework also enabled a series of insights of wider theoretical and practical relevance. These are summarized below.

3.1 Theoretical contributions

As noted in Chapter 3, agent-based models of the kind developed in this thesis are also, by necessity, models for the formation of the archaeological record. As such, they can enable important theoretical insights that extend beyond toolstone procurement proper. Thus, in Chapter 3 I demonstrated that

archaeological assemblages *cannot* reflect the average composition of discrete mobile toolkits (cf., e.g., Brantingham, 2003), even if such toolkits consisted entirely of implements with identical use-lives and discard probabilities. Similarly, in Chapter 5 I demonstrated that lithic refitting across sites is, despite its hypothetical potential to inform us of the sequence of individual or group movements across a region, likely not an avenue that is worth pursuing, even if the costs of evaluating refits for all archaeologically known pieces was zero. Furthermore, the analyses presented in Chapter 5 also indicate that some types of lithic recycling may have been a common but possibly undetectable occurrence even in very resource-rich environments (cf., Amick, 2014). Overall, these results underscore the utility of agent-based models in evaluating the potential of different research avenues and the implications of the palimpsest nature of the archaeological record.

In this thesis I have argued that such models should strive to be minimally realistic. Developing minimally realistic models is not easy, as doing so presupposes exploring a range of assumptions and mechanisms that abstract models need not explicitly contend with; it also requires finding a more delicate balance between simplicity and realism. However, as demonstrated in this work, the 'details' that are glossed over in models such as Brantingham's are not always inconsequential, and the onus for demonstrating that they are must fall on the modeller, not on her or his audience. Because of this, I suggest here that abstract models which are not *easily* adjustable to employ real units (e.g., grams of stone, hours of work, *et cetera*) should be treated with a great deal of caution, as they are likely severely underspecified.

With regards to lithic raw material sourcing, my work underscores the need to pay close attention to all aspects of past resource selection, including source avoidance, in order to maximize the inferential potential of this important source of information on past lifeways. Indeed, the results of Chapter 4 show that we should not be too hasty in dismissing unutilized sources as unavailable in the past or, more generally, in *assuming* that the present-day environmental distribution of lithic resources is of questionable relevance (cf., Dibble, 1991). They also show that there is much to be learned from detailed examinations of 'local' resource use, which is often glossed over as uninteresting or easily explained (e.g., Mellars, 1996). As shown in Chapter 4, it is useful to conceptualize sources as nodes in a network of alternatives, since as demonstrated in Chapter 3, the utilization of any given source will be influenced by its placement relative to said alternatives.

Finally, the work presented in this thesis raises questions regarding the conceptualization and interpretation of key binary concepts such as embedded versus direct procurement (e.g., Binford, 1979; Gould and Saggers, 1985) and provisioning of places versus provisioning of individuals (Kuhn, 1995), which have been widely used to draw inferences from provenance data. With regards to the latter, Chapter 5 shows that neither the frequency of residential moves, nor the duration of residential stays, need to be strategically related to the provisioning of places versus the provisioning of individuals (cf., Kuhn, 1995). With regards to the former, it is typically assumed that a given raw material type was *either* collected from the inhabitants of a specific site casually while performing other activities at likely a negligible cost (i.e., embedded *sensu* Binford, 1979 – see, e.g., Tomasso and Porraz, 2016; Oestmo et al., 2020) *or* that it was collected during special purpose trips (direct procurement *sensu* Binford, 1979). This reasoning, as pointed out by others also (see, e.g., Surovell, 2009) is flawed. In Chapter 1, I argued that while lithic materials were probably not the main drivers of scheduling activities due to their predictability, their critical role in subsistence suggests they are unlikely to have been the least

important ones either. Consequently, the targeting of lithic resources in the context of embedded procurement likely represented a compromise, with an implied cost of lost opportunities.

Beyond this, and as demonstrated in Chapter 3, constant access to lithic resources cannot be guaranteed by chance encounters with raw material sources, even in resource-rich environments; consequently (see above), most procurement episodes must have entailed *some* purposeful deviations from the least-cost paths linking a site to exploited non-lithic resources (see also Surovell, 2009), once again implying an added cost. Indeed, in Chapter 4 I demonstrated that data from the Bau are consistent with a scenario of fully embedded procurement in which sources are nevertheless purposefully and carefully targeted, sometimes with possibly substantial added effort (i.e., carrying rocks for some additional 40 minutes or more in 25% of evaluated cases), even if extraction costs are ignored (see also Elston, 2013; cf. Ekshtain et al., 2017). A careful reconsideration of the binary distinction between these two modes of procurement is therefore warranted, as it may be leading us astray. Indeed, a substantial presence of so-called 'semi-local' and/or 'exotic' materials within an assemblage, particularly if derived from a single or small number of sources, is often interpreted (e.g., Romagnoli, 2015) as indicating logistical as opposed to residential mobility - another problematic binary - but the results presented in Chapter 5 demonstrate that this may be unwarranted. Indeed, depending on the frequency of residential moves, more than half of an assemblage could realistically have been collected while residing elsewhere and transported in the course of regular camp moves. Depending on which areas of the landscape were settled, and the spatial configuration of sources, such imported materials could well have been collected from but a handful, or perhaps even a single, raw material source. It is only through simulations that such possibilities may be evaluated.

3.2 Practical contributions

An important contribution of this thesis is the release of the code used to implement the proposed approach under an open-source license. Indeed, only open-source software (e.g., R, Python, GRASS GIS) was used in this work, and only freely available geospatial data. The framework developed here should therefore be easy to adapt and apply in any other context where suitable provenance information is available, and where similar baseline behavioural assumptions can be made. Importantly, this framework has applications that extend beyond the research questions pursued here. The minimally realistic model proposed in Chapter 5, for instance, may prove useful in pinpointing areas of increased archaeological potential (i.e., those that are compatible with hypothetical site placement and known archaeological variability), since it is spatially explicit. Indeed, as discussed in Chapter 5, the implementation of a minimally realistic model can provide insight into the number of archaeological sites that we may expect to find in a given region, as well as the expected frequencies of habitation episodes for these. Moreover, because they enable the systemic effects of isolated variables and parameters to be studied in detail, minimally realistic agent-based simulations, and the resource selection model proposed in Chapter 4, should prove useful in determining the impact of unavoidable biases and errors in sourcing datasets, introduced by, for instance, recent anthropic modifications to the landscape. Along the same lines, simulations should prove useful in guiding the selection of optimal sourcing methodologies, so as to maximize inferential potential while minimizing the cost of sourcing lithics based on the specific geologic and geographic characteristics of a given region. Finally, as discussed in Chapter 5, simulations can give insight into the number of sites.

4 FUTURE DIRECTIONS

The envisioned practical applications discussed above highlight important future research directions facilitated by the present work. Particularly enticing, given the known changes to land cover, is the prospect of being able to quantify the likely impacts of the omission or incorrect characterization (e.g., of extents of exposure) of raw material sources, or other similar errors, on interpretation. While the analyses presented in Chapter 4 lend further weight to the suggestion that the lithic landscape in the area surrounding the Bau has not changed substantially since the initial occupation of the site (e.g., Browne and Wilson, 2011), I did identify a problematic source in Chapter 5, and it is clear that substantial changes did occur in many other regions. This novel avenue of research, first hinted at in Chapter 3, will therefore be pursued in future analyses of the Bau dataset, and subsequently of datasets from sites and regions.

In addition to pursuing such entirely new research directions, future work will also focus on refining the minimally realistic model. One aspect that requires greater attention is the distance parameter used for residential mobility, since at present the impact of using different settings is unknown. More importantly, a method is needed for reliably determining which "optimal" sources the simulated agent should target from a site, given the access costs. Currently no access cost cut-off is used, and as a result a substantial amount of noise is introduced to the simulation outputs. Finally, a more refined implementation of sedimentation processes is needed, so as to produce assemblages that are more realistic in terms of their size and composition.

Beyond this, future work should integrate faunal and techno-typological information available for the Bau, now that the intrinsic properties of the provenance data are well-understood. Given my observations in Chapter 5, it would be particularly useful to look at variability among tools versus waste materials, as this could clarify the degree to which sources exploited locally were also targeted at other sites from which materials were imported to the Bau. Information on the degrees and nature of lithic reduction will also be considered in future work, since the models presented in this thesis have considered how lithics may have been procured and discarded but have not focused on the intermediary stages of use. A more distant goal is to explore the feasibility of incorporating multiple agents, so as to investigate the possible effects of social contacts on lithic raw material variability, and determine the degree to which the latter may be informative with regards to the former.

Most importantly, however, the approach proposed here must be applied to other sites and regions, so as to better understand variability in land use across time throughout the Neanderthal range. As a first step in this direction, the model could be applied to La Combette, a younger Middle Palaeolithic site located near the Bau, for which a partly compatible provenance dataset exists (Wilson et al., 2018). Such application will lead not only to a better understanding of resource use in the region, but hopefully also to a more flexible model that could be applied with greater ease at sites where the available provenance information is less precise than at the Bau, as is in fact the case at La Combette. Applications to other sites in the region that are contemporaneous with the Bau are also needed, because they would enable ground-truthing some of the important insights discussed in Chapter 5 (e.g., regarding zones of compatibility of residential mobility with archaeological observations). Unfortunately, no such sites with compatible provenance data exist, so substantial prior work is needed. Beyond the studied region of southeastern France, viable, impactful applications to Middle Palaeolithic sites from the Iberian Peninsula and southwest Asia can be envisioned.

5 Concluding remarks

In this thesis I have shown that simulating lithic resource management and selection in order to make quantitative predictions with respect to archaeological raw material variability based on a well-defined behavioural framework, built on a minimalist and tested set of assumptions, is both feasible and necessary. Indeed, as shown in chapter 5, interpreting the record at ethnographic scales (e.g., Feblot-Augustins, 1993, 1999; Raynal et al., 2013) is problematic, and so is incorporating ethnographic insight naively into explanatory models of land use (e.g., *assuming* the size of daily exploitation territories based on ethnographic observations, e.g., Ekshtain et al., 2014). Such ethnographic insight is certainly useful (see Marlowe, 2005), but only insofar as its relevance can be independently demonstrated. These observations are not new, however (e.g., Wobst, 1978); the original contribution of this thesis consists instead of providing a concrete foundation for a viable alternative.

6 References

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