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 One
Introduction

1 Rationale and Goals

Lithic artifacts constitute ubiquitous and often sole surviving evidence of past human activities for much of the evolutionary history of our genus. They thus provide comparable vectors of analysis across a wide range of environmental and temporal contexts, revealing key aspects of past adaptations. The raw materials from which such artifacts were manufactured can often be traced to specific natural deposits, enabling important insights into factors such as procurement costs that would have shaped past lithic resource management decisions and consequently the variability observable in archaeological assemblages (e.g., Dibble 1991; Kuhn 1995; Andrefsky 2008 and references therein); they also provide crucial clues regarding overall land use strategies at different scales (e.g., Féblot-Augustins 2009; Frahm et al. 2016; Turq et al. 2017). It is for these reasons that lithic provenance studies have long been considered important in elucidating key aspects of human/environment interactions in prehistory. Notwithstanding their potential, there are two major challenges that provenance studies face. The first consists of identifying and characterizing original procurement locations accurately and with meaningful precision across landscapes that may have changed substantially both during and since the initial deposition of the investigated assemblages (e.g., Dibble 1991; Turq 2005). Much progress has been made in this regard over the last few decades, both in terms of the identification and cataloguing of exploitable naturally occurring raw material deposits (e.g. Biró 2009; Fernandes 2013; Pereira et al. 2016), and in terms of the development of novel characterization and classification techniques for materials used in prehistory, including chert (e.g. Fernandes et al. 2007; Parish 2011; Olofsson and Rodushkin 2011; Brandl et al. 2018) and obsidian (see Kuzmin et al. 2020). Nevertheless, sourcing archaeological lithics continues to be a very resource-intensive task that often comes short of providing conclusive answers regarding specific procurement locations.

A second challenge, and one which is the focus of this thesis, pertains to the interpretation of the provenance data: even if we could identify the procurement location of all stone artifacts with perfect accuracy and precision, we would still face the daunting task of interpreting static archaeological frequencies in terms of dynamic human behaviours. Lithic artifacts are a versatile component of wider organizational systems and could have been used in multiple contexts, and for multiple purposes, throughout complex life histories (e.g., Andrefsky 2008). Inferring behaviours and their determinants from palimpsests of discarded, lost, or abandoned end products is therefore difficult, and it is particularly so in the case of assemblages created through the agency of different hominin species, where the fundamental cognitive processes and abilities underpinning observed variability may not have been the same as those that underlie our own practices. As a consequence, most explanations of raw material variability in Middle Palaeolithic contexts incorporate, out of necessity, a series of assumptions that have not been rigorously tested.

Agent-based modelling has great potential for addressing this problem because it enables the systemic effects of different assumptions to be examined in detail. However, the most promising applications so far have employed abstract units as well as abstract definitions of space and time (e.g., Brantingham 2003; Barton and Riel-Salvatore 2014), and it is difficult to evaluate whether the simplifying assumptions underpinning such abstractions are valid. Consequently, a primary goal pursued in this thesis is the development of a minimally realistic agent-based methodology for inferring one aspect of past adaptations, namely land use, on the basis of archaeological raw material variability. Specifically, the approach pursued here aims to be as simple as possible while being spatially and temporally explicit and employing real and well-defined units (e.g., grams of stone) as well as behavioural rules that make sense for a given temporal and geographic context. A parallel goal is the development of a resource selection model that can be easily integrated into such agent-based framework, one built strictly on the basis of archaeological observations and which can account equally well for both exploited and unutilized raw material sources. While these goals are met using data from a specific site, namely the Bau de l'Aubesier (southeastern France), the resulting methods are expected to be broadly applicable in other contexts as well.

What follows is an overview of the specific research questions this thesis seeks to answer, contextualized by means of a background discussion of stone procurement studies in Middle Palaeolithic contexts. I then provide a general summary of the methods and data I use, outlining the process through brief summaries of the chapters that are included in this work.

2 Research questions

The research questions pursued in this thesis reflect an overall concern with letting provenance data speak for themselves rather than forcing a fit to models developed using other lines of evidence (e.g., ethnographic analogy). They can be summarized as follows:

1. What can be learned from re-evaluating a neutral model of lithic procurement (Brantingham 2003) in terms of developing an alternative, agent-based framework for interpreting provenance data?
2. Can we determine the likely extents of the territories over which lithic resources were locally exploited by Middle Palaeolithic hominins without relying on untested and possibly untestable assumptions?
3. Can we determine the extent of the likely home ranges of Middle Palaeolithic individuals and groups based solely on lithic provenance data and a minimal and clearly justified set of assumptions?
4. What, if anything, can provenance data tell us of how Neanderthals may have conceptualized stone resources and, more broadly, about the cognitive processes underpinning their use?

3 Background

3.1 The European Middle Palaeolithic

The term Middle Palaeolithic refers to a phase of development in techno-economic organization that is traditionally characterized by a focus on flake tools produced through lithic reduction sequences that employ prepared core techniques, most notably Levallois (e.g., Burkitt and Childe 1932; Clark 1969; Adler et al. 2014; Soriano and Villa 2017), and more broadly by a suite of innovations (e.g., Fontana et al. 2013; Hérisson et al. 2016) implying increasingly greater behavioural and executive flexibility, planning complexity, and control (e.g., White et al. 2011; Kuhn 2013; see also Malinsky-Buller 2016). In Europe, it is chronologically constrained between the onset of MIS 8 and 3, or roughly 300-250kya (e.g., White et al. 2011; di Modica et al. 2016; Hérisson et al. 2016; Soriano and Villa 2017) and the appearance of early Upper Palaeolithic or transitional technocomplexes such as the Châtelperronian between ca. 50-40kya (e.g., Hublin et al. 2012; Richter 2016). It spanned variable areas from the Mediterranean to roughly 55° North (see Nielsen et al. 2017 for a discussion) and the entire longitude of the continent, depending on prevailing climatic conditions (e.g., Roebroeks et al. 2011). Lastly, it is associated with Neanderthals (e.g., Roebroeks and Soressi 2016; but see e.g., Harvati et al. 2019).

Kuhn (2013) has argued that true innovations in the Middle Palaeolithic were few (see also Stiner 2013), amounting to hafting, pyrotechnology, and the use of pigments, the rest of the technological systems representing a reorganization of an already existing repertoire. While other inventions presaging the eventual onset of the Upper Palaeolithic, such as specialized bone tools (e.g. Soressi et al. 2013), cave art and other forms of symbolic material culture (e.g., Zilhão, 2012; Radovčić et al. 2015; Hoffmann et al. 2018a; Hoffmann et al. 2018b) are also sporadically evidenced in Middle Palaeolithic contexts, behavioural plasticity, reflected in variable technological and organizational responses to circumstances, is increasingly considered to be a hallmark. Indeed, the apparent simplicity of Middle Palaeolithic artifacts, which consist mostly of processing tools such as scrapers, notches, and denticulates (e.g., Richter 2016; Ruebens and Wragg Sykes 2016) betrays a great deal of tactical and strategic sophistication in their procurement, manufacture, and use (e.g. Kuhn 2013; Turq et al. 2013; Locht et al. 2016; Picin 2018), as well as pronounced regional differences, particularly in the case of younger assemblages (e.g. Ruebens and Wragg Sykes 2016; see also Richter 2016; cf. Daujeard et al. 2016).

Novel landscape utilization strategies emerging during the Middle Palaeolithic are evidenced by various proxies indicative of increased and varied mobility patterns as well as sophisticated regional-scale organization and scheduling of activities (cf. Binford 1989). These proxies include seasonal and possibly logistic (*sensu* Binford 1980) utilization of sites (e.g., Daujeard and Moncel 2010; Delagnes and Rendu 2011; Ashton and Scott 2016), which in some cases attest to monospecific hunting strategies (e.g., Daujeard and Moncel 2010; Richter 2016), substantial fragmentation of reduction sequences and differential processing and transport of raw materials (e.g., Delagnes and Rendu 2011; Raynal et al. 2013; Turq et al. 2013; Ruebens and Wragg Sykes 2016), a widespread negative correlation between retouch intensity and artifact densities (see Kuhn 2013 and references therein), and the general diversification of lithic reduction methods to fit different, situationally specific mobility requirements (e.g., Turq et al. 2017).

The behavioural flexibility characteristic of Middle Palaeolithic adaptation seems to have been underpinned by an excellent knowledge of resources over relatively large areas (e.g., Raynal et al. 2012) and overall exploitation strategies aimed at optimization. Beyond that, however, it is likely that explanations for specific adaptations (e.g., the use of specific tool types, specific reduction methods for specific raw materials, tasks, and situations, or regional trends in raw material management) can only be provided for specific contexts, without generalizing to the entire Middle Palaeolithic record (see Eixea 2018). For instance, temporal trends are evidenced in some regions such as Britain (e.g., Ruebens and Wragg Sykes 2016) and the Aquitaine Basin (e.g., Turq 2013) but seem absent in others (e.g., Spain – de la Torre et al. 2013; SE France – Daujeard and Moncel 2010). Similarly, stone management in the Aquitaine (e.g., Turq 2013) appears to be quite different from what is evidenced in southeastern France (e.g., Raynal et al. 2013). Overall, there is a growing consensus that the Middle Palaeolithic cannot be viewed as a homogeneous, static entity.

3.2 Stone resources and the Middle Palaeolithic record

As the preceding discussion has already hinted, much of our understanding of Middle Palaeolithic lifeways derives from evidence preserved in stone. Indeed, owing to their durability and varied uses, lithic materials are ubiquitous in Middle Palaeolithic assemblages, providing comparable and sometimes only vectors of analysis between sites that may otherwise be quite dissimilar in terms of geographic and temporal context, preservation potential, and resource availability or use. Stone artifacts have therefore been used to draw inferences at a variety of scales, ranging from the cognitive processes reflected in the manufacture of individual pieces (e.g., Stout 2011; Muller 2017), to the land use strategies employed by hominins (see above and section 1.3.3.2 below). It is clear that, combined with other lines of evidence, lithics have the potential to inform us of many aspects of Middle Palaeolithic adaptations. However, it is important to recognize that there are some fundamental differences between toolstone and other resources that hominins regularly exploited, and that the distinguishing characteristics of lithic materials must be considered carefully before incorporating lithic data into more comprehensive explanatory frameworks, as they may inform us of potentially very different processes and behaviours, operating at different spatial and temporal scales (e.g., Vaquero et al. 2017).

Some of the distinguishing characteristics of lithic resources are as follows:

a) Raw material sources are essentially static when considered at human timescales. Consequently, the costs of procurement are highly predictable provided an area has been inhabited long enough for resource distribution and topography to be known.
b) The nature of the raw materials (e.g., knappability, durability, ease of extraction) can vary substantially between sources, but such differences, when viewed at human timescales, tend to be fixed. The benefits afforded by different procurement alternatives are therefore also highly predictable if a region is well-known.
c) Good quality raw materials occur over a limited exposure. Often, though not always, usable materials are found in spatially constrained settings (e.g., a discrete outcrop or secondary deposit) which can theoretically be identified from archaeological pieces based on structural, chemical, and physical signatures resulting from unique geological histories (see e.g., Luedtke 1992; Malyk-Selivanova 1998; Fernandes et al. 2007).
d) Most lithic raw materials are a non-renewable resource when considered at human time scales. This may be important to consider when investigating the long-term exploitation of primary sources (see, e.g., Dibble 1991).
e) As attested by use-wear studies, traces left on other materials (e.g., cutmarks on bone), and their very ubiquity, lithic raw materials were, throughout the Palaeolithic, an essential part of adaptation for members of our genus, both for the extraction and processing of resources for consumption, and for the creation of other tools.
f) As a consequence of ***c*** and ***d***/***e*** above, and because other resources essential to humans (e.g., food and shelter) are not predictably found at lithic raw material sources, toolstone has to be transported to where it may be needed, resulting in a human-mediated displacement across the landscape.
g) Stones are heavy and may contain flaws that are difficult to identify prior to use. As is both ethnographically (e.g., Sillitoe and Hardy 2003) and archaeologically (e.g., Barkai et al. 2002) documented, it often pays off to process the materials, to some extent at least, prior to transport.

h) Stone tool making is a reductive process, and this has several implications. First, as a piece of stone is worked, it gets progressively smaller, decreasing its usability potential over time. Second, at least parts of the process of manufacture can be reconstructed through refitting and technological studies (see, e.g., Andrefsky 2009 and references therein), thereby giving insights into overall strategies employed, and tactical decisions made, by individual tool makers. Third, as stone is transported, the reduction process may be fragmented across sites (see ***f*** above), thus giving us a glimpse of how a site fit within a wider land use pattern (e.g., Moncel et al. 2014).

i) Finally, lithic implements are durable, and we can reasonably expect them to survive indefinitely in archaeological contexts in the absence of post-depositional processes that would physically remove them from a site. Conversely, their durability, combined with the costs of transport (***f*** above), imply that the potential for lithic materials to have been exposed to multiple episodes of human alteration or agency is high – for instance, materials may have been recycled long after their original discard or abandonment for a very different purpose by a totally unrelated individual (e.g., Turq et al. 2013).

In short, stone was a fundamentally important (e), predictable (a, b) non-renewable (d) but potentially very abundant resource, whose transformations through human agency can be investigated in good detail (h) by virtue of its preservation potential (i). Since transporting rocks necessary for livelihood (e) over great distances comes at a cost (g), the spatial distribution of stone deposits was likely a strong determinant of overall settlement and mobility strategies (e.g., Mellars 1996; see also Doronicheva et al. 2016). However, given the predictability of procurement (a), particularly compared to that of other resources, stone provisioning is unlikely to have been the main determinant of most scheduling activities. On the other hand, some amount of stone is likely to have been carried by individuals to ensure supply when needed (e.g., Kuhn 1995). At a minimum then, and because the geographic origin of toolstone can often be ascertained (c), investigating lithic materials should enable us to elucidate aspects of both group and individual mobility.

3.3 Toolstone procurement studies

3.3.1 Historical considerations

Prehistorians have long recognized that raw material availability and characteristics affect assemblage variability (e.g., Moulin 1903; Dibble 1985; Kuhn 1991; see also references in Turq 2005). Focused, systematic research into the provenance of archaeologically exploited stone has a shorter history, however. Important studies were conducted in the 1960s and 1970s (e.g., Valensi 1960; Renfrew et al. 1965; Renfrew 1969; Kozlowski 1972; Luedtke 1976 – see also Delage 2003 for a more detailed discussion) against a backdrop of shifting theoretical perspectives and increased interdisciplinarity. In terms of theory, archaeology as a whole was moving away from a culture-historical paradigm and towards an emphasis on understanding behaviours and cultural processes (see, e.g., Trigger 2006), with parallel developments in cultural anthropology (e.g., cultural ecology). Within approaches that increasingly saw lithic technology as a dynamic component of wider adaptive systems, understanding toolstone procurement strategies, and as a corollary identifying the location of potential raw material sources, became, at least in principle, critically important (e.g., Sellet 1993; Andrefsky 2008). Increasing interdisciplinary collaboration, on the other hand, exemplified by, for instance, the International Flint Symposium (first held in 1969 – see, e.g., Sieveking and Hart 1986), led to the development of characterization methods that enabled more reliable source attributions for archaeological artifacts, as well as to a good understanding of the distribution and geological context in which sources of usable stone occurred in many regions (e.g., Leonoff 1970; Luedtke 1976; Gramly 1978; Morala 1980).

The 1960s and 1970s were also an important period in terms of developments in hunter-gatherer studies (e.g., Lee and DeVore 1968), which strongly shaped how lithic raw material provenance data would be interpreted in Middle Palaeolithic contexts later on. For instance, the often-noted two-hour-walk foraging radius is attributable to Richard Lee's work among the Ju/'hoansi (Wobst 1978), while many other constructs regularly used in the literature today can be traced, directly or indirectly, to Lewis Binford's work among the Nunamiut. The influence of this body of work on subsequent interpretations of lithic provenance data is difficult to overstate. Binford's idea of embedded procurement, for example, though not new (see Luedtke 1976), provided a theoretical justification for interpreting maximum transfer distances in terms of home range sizes (e.g., Féblot-Augustins 1993, 1999; Kuhn 1995; Mellars 1996), still a common practice today. Similarly, his distinction between residential and logistic mobility has framed many interpretations over the last three decades (e.g., Féblot-Augustins 1993; de Soler et al. 2020). His concept of curation, introduced in the 1970s, continues to be similarly influential, in part because, as Andrefsky (2008) noted, "it linked stone tools to mobility patterns".

Be as it may, by 1980 the necessary basic theoretical and methodological building blocks were in place, and over the following decade provenance studies became a major focus in Palaeolithic research in France and elsewhere in Europe (e.g., Floss 1994; Mellars 1996; Turq 2005; Biro 2009; Feblot-Augustins 2009; see also Delange 2003). The 1980s thus witnessed the creation of the first major lithotheques in France, Hungary, and Switzerland (Biro 2008), as well as a series of publications by a handful of French researchers (e.g., Geneste, Turq, and Demars), working mainly in the Aquitaine Basin, and which would become the basis for later syntheses that continue to influence interpretation today (e.g., Féblot-Augustins 1993, 1999; Mellars 1996).

Among the most enduring contributions of this literature are Geneste's definitions of local, intermediate, and distant procurement zones. As summarized later by Mellars (1996) and others (e.g., Feblot-Augustins 1993), work in southwestern France in the 1980s pointed to a strong reliance (70+% of lithics) on materials collected at up to 4-5 km from camps, discarded or abandoned at all stages of lithic reduction (though seldom in the form of retouched implements), and the frequent (i.e., ca. 80% of cases) presence of small quantities of "terminal products" transferred over distances of up to 100 km from a relatively large array of sources. Diverse raw materials, procured from sources found at intermediary distances (i.e., 5 to 20 km), were also a recurrent characteristic of assemblages from these sites, representing a mix of utilization patterns typical of materials collected at more distant sources and at local ones. For Mellars (1996), some of these later materials, namely those collected from sources located at 6 to 12 km from sites, could have been collected during occasional forays within an "extended foraging radius". The more distant materials (i.e., 20 - 100 km) were typically thought to reflect the mobility of Neanderthal groups over their home ranges. Mellars (1996) noted that a site may have been used by multiple groups exploiting different territories, but many other researchers (e.g., Feblot-Augustins 1993) worked under the assumption that the distribution of distant utilized raw material sources provided insights into the movements of discrete groups, and that maximal transfer distances could be used to provide meaningful estimates of their home range sizes.

Since the late 1990s our understanding of the geographic distribution of usable raw material sources across the Neanderthal range has improved considerably, and many assemblages, covering a wide geographic range, have now been analyzed from the point of view of lithic raw material provenance. Together with important developments in sourcing methodologies that resulted in cheaper and faster data acquisition (e.g., pXRF), improved reliability, and/or greater informational potential (e.g., Fernandes et al. 2007), we now have a substantially expanded dataset on Middle Palaeolithic toolstone procurement. However, there have been relatively few major developments in terms of how data are interpreted; indeed, the frameworks proposed in the 1980s and 1990s on the basis of a handful of sites continue to colour, if not dominate, approaches to the interpretation of Middle Palaeolithic raw material procurement data. There continues to be an overriding concern with the utilization of distant materials, either to elucidate regional patterns of raw material transfers or to assess the possibility of inter-group exchanges, and by and large the problem of raw material procurement continues to be framed in terms of ethnographically-derived models of embedded or direct procurement within the context of logistic or residential mobility.

This is not to say that no important theoretical contributions have been made; there have certainly been exciting new developments in terms of the availability of novel approaches to interpretation, ranging from agent-based modelling (e.g., Brantingham 2003), GIS analyses (e.g., Ekshtain 2016), to more theoretical approaches based on estimates of energy consumption (e.g., Verpoorte 2006). There is also a greater awareness of the potential role the recycling of materials may have in explaining instances of long-distance transport (e.g., Turq et al. 2013), and a greater emphasis has been placed on the development of new methods aimed at understanding resource utilization and land use at smaller scales (e.g., Browne and Wilson 2011; Frahm 2016). However, the impact of these advancements on overall syntheses of Middle Palaeolithic raw material provisioning has been minimal.

3.3.2 An overview of contributions

Raw material procurement studies came to the fore in Middle Palaeolithic research at a time when the planning and organizational abilities of Neanderthals, and more broadly their capacities for symbolic thought and cooperation, were under heavy assault. Provenance studies contributed to debates on Neanderthal abilities in a number of ways. For example, they provided data indicating that Neanderthals did not always employ expedient technologies (e.g., Soressi and Hays 2003; see also Hiscock et al. 2009; Kuhn 2013) and that they had a good knowledge of the environments they inhabited (e.g., Féblot-Augustins 1993; Raynal et al. 2012; Raynal et al. 2013), exploiting them strategically. Such strategic exploitation is thought to be reflected in the directions and distances from which stone resources were brought in, often interpreted in terms of residential mobility in the case of resources not available in the immediate vicinity of the sites at which they were discarded or abandoned (e.g., Feblot-Augustins 1993, 1999). It is also thought to be reflected in the provisioning of sites (*sensu* Kuhn 1995) in cases where the absence of raw materials was known (e.g., di Modica et al. 2016; Malinski-Buller 2016), and more broadly in a strategic adjustment of exploitation strategies based on expected raw material availability (e.g., Braun 2005; Dogandžić and Đuričić 2017 and references therein; Delpiano et al. 2018).

Such studies also revealed Neanderthals were selective in their use of stone resources, often, but not always, preferentially targeting outcrops of higher quality rocks (e.g., Wilson 2007; Eixea 2018) despite being perfectly capable of applying complex reduction techniques (e.g., Levallois) to a wide range of materials with potentially lower access costs, including limestone (e.g., Dogandžić and Đuričić 2017;

Eixea 2018; Eixea et al. 2020), basalt (e.g., Reynal et al. 2013; Santagata et al. 2017), phonolite (e.g., Santagata et al. 2017); quartzite (e.g., Eixea 2018; Eixea et al. 2020), and andesite (e.g., Panagopoulou 2004; see also Daffara et al. 2019). Indeed, raw material provenance data has been used to explore the degree to which different selection criteria were important (e.g., nodule size, knapping quality, functional performance – e.g., Browne and Wilson 2011; Wilson et al. 2018), how these criteria changed through time at individual sites (e.g., Wilson and Browne 2014), and also how raw material selectivity varied across different regions (e.g., Eixea 2018). Overall, research into toolstone procurement has served to highlight the versatility of Neanderthal adaptation, even if more limited than evidenced with anatomically modern humans.

Provenance studies also revealed that in most instances lithic raw materials were transferred over shorter distances during the Middle Palaeolithic than in subsequent periods. As noted by Féblot-Augustins (2009) amongst others, almost all sites appear to have been provisioned with materials typically found within what may be called an 'extended foraging radius' of up to 12 km or so, covering areas reachable through occasional daily forays (e.g., Mellars 1996). Longer transfers, though almost always documented, appear to result from the discard of generally high-quality materials carried by individuals as part of their mobile toolkits, typically retouched implements or flexible matrices (e.g., Meignen 2009; see also Hiscock et al. 2009; Turq et al. 2013; Turq et al. 2017). Such long-distance transfers are also normally restricted to areas that may have corresponded to home ranges of groups or individuals that made use of the sites (see below), as they only exceptionally exceed 100 km (see Feblot-Augustins 2009). While macro-regional differences are attested, reflecting perhaps the underlying differences in the geographic distribution of raw-material-bearing geological formations (Duke and Steele 2010) or resource availability more broadly, the overall data suggests inter-group exchanges *of stone* were uncommon, if they occurred at all. This, in turn, has implications in terms of the complexity of social organization (e.g., size of interaction networks – e.g., Eixea 2018).

The contribution of basic data on hominin-environmental interactions is, of course, useful beyond the relatively narrow scope of debates on the degree of Neanderthal behavioural modernity. As noted above, provenance studies can hint at the *extent* of the territories exploited by Neanderthals at different analytical scales (see below) as well as at the *nature* and *degree* of mobility within those territories (see, e.g., Féblot-Augustins 1993; Fernandez-Laso et al. 2011; Raynal et al. 2013; see also Cole 2002), particularly when combined with other lines of evidence such as stable isotope and faunal studies. Viewed at a regional level and drawing on data from multiple sites, provenance data can further be used to examine connections or mobility corridors between different geographic zones (e.g., Turq et al. 2017; Eixea et al. 2020), and diachronic shifts in the apparent size of the territories have been interpreted by some as signaling transitions in subsistence patterns and socio-economic organization (e.g. Zilhão 2001; Ashton and Scott 2016). Indeed, the ability to provide insights into mobility, and perhaps social interactions, is considered by many to be the most important aspect of provenance studies (e.g., Larick 1986; Takács-Biró 1986; Mellars 1996). The basic picture that has emerged in terms of territorial exploitation to date, and which has not changed substantially since the 1980s, can be summarized as follows:

1. <u>Area within which daily foraging activities occurred</u>: Typically, 5 - 10 km from a site, corresponding to a *maximum* of ca. 80 - 315 km^2 (e.g., Hayden 2012; see also Mellars 1996; Wilson et al. 2018). This estimate is based on considerations of the radius within which the bulk

of the archaeological materials were procured (though further details are often not given), and the close agreement with ethnographic observations (see above; see also e.g., Mellars 1996).

2. Group home ranges: The extent of the territories regularly exploited by the group(s) that spent some time at a site within their system of residential mobility have been discussed based on attested transfer distances as well (e.g., Mellars 1996; Steele 1996; Cole 2002). Typically, transfer distances of between 20 - 100 km are seen as indicating home range sizes, and consequently result in estimates for the latter of at least ca. 1,000 km^2 (e.g., Boyle 1998) and up to more than 10,000 km^2 (e.g., Féblot-Augustins 1993; see also Wilson et al. 2018), depending on how one interprets the often very muddled uses of the concept of "territory" (e.g., Raynal et al. 2012; Turq et al. 2013). These estimates are in line with estimates from some carnivore models (e.g., Walker 2014) and some ethnographic data (e.g., Marlowe 2005), but other lines of evidence suggest these estimates may be too high (see below). The presence of materials from distant sources has been interpreted as indicating a relatively high degree of residential mobility, since lengths of residence must have been shorter than the time spent by materials in mobile toolkits (e.g., Cole 2002), but this aspect is typically discussed in qualitative terms.

3. Individual ranges - landscapes of habit, zones of socioeconomic influence, "tribal" range, or "mating network": Some researchers (e.g., Gamble 1999 and references therein; Pearce and Moutsiou 2014; see also Churchill 2014) interpret maximum transfer distances in terms of territories used by individuals and those with whom these individuals interact in some capacity. It is often difficult to distinguish, based on the usage, whether this is what many authors have in mind when discussing Neanderthal territories, or whether it is group home ranges, or something entirely different.

Beyond this, raw material provenance also supplies critical data for understanding tactical and strategic decisions in the use of stone that directly influenced assemblage variability, and consequently our interpretations of technological organization as well as typology. In essence, the real or anticipated costs of acquiring different raw materials constrained choices, and the properties of the rocks worth getting (e.g., fracture characteristics, nodule sizes and shapes) are typically thought to have affected both tool morphology and the choice of reduction techniques (e.g., Andrefsky 1994; Braun 2005; but see Eren et al. 2014; Garefalakis et al. 2018). Moreover, said costs may also explain the different treatment of materials (e.g., high-quality materials being transferred over longer distances in specific package types); there are indeed many examples where different degrees of mobility are thought to be attested to by different types of implements or reduction strategies (e.g., Turq et al. 2013; Faivre et al. 2014; Ruebens and Wragg Sykes 2016; Turq et al. 2017).

3.3.3 Interpretive challenges

While a substantial corpus of data on Middle Palaeolithic toolstone procurement has now been compiled (see section 1.3.3.1 above), numerous issues hinder its interpretation. Some of the most salient ones are discussed below:

Terminology: Critical terms underpinning both the interpretation and reporting of basic data, such as *local*, *exotic*, *group*, *mobility*, *territory*, or *home range* are in most instances poorly defined, and the theoretical assumptions underpinning their use are seldom explicitly discussed and justified. Consequently, it can be difficult to integrate the results of studies conducted in different regions. A few examples are worth a closer look:

a. *local*: This term, while mostly used to denote materials procurable within 5 km or less, sometimes also refers to materials procurable within 10 km of a site (e.g., Moutsiou 2011; de la Torre 2013; Eixea 2018) or more (e.g., 12 km in Cole 2002; 20 km in Adler et al. 2014), and often it is not defined at all (e.g., Martinez and Rando 2001; Zilhão 2001; Blaser et al. 2002). While the reasoning behind the choice of a cut-off value (if any) to define "local" often makes sense within the context of a specific paper, it can lead to misunderstandings when multiple studies are compared in terms of how materials were procured, and by whom (e.g., by individual site residents in the context of daily foraging activities, or while residing at other nearby sites and then brought in during residential moves). This is not a trivial problem (cf., Mellars 1996) because it has important implications with regards to the scale of Neanderthal activities: do these "local" materials inform us of daily exploitation territories, of the home ranges of one or more groups, or perhaps of something else? Indeed, the lumping together of the typically dominant component of assemblages as "local" also serves to render this local range somewhat of a *terra incognita*, concealing potentially very interesting and highly informative differences and similarities in the utilization of such areas across the Neanderthal range. Few studies (e.g., Frahm et al. 2016) have so far focused squarely on evaluating the use of these "local" areas on the basis of the provenance of stone.

b. *mobility*: Although the potential of sourcing studies to inform us of past mobility patterns is a key perceived contribution (see above), seldom is the term defined or discussed in sufficient detail. Neanderthals may well have been very mobile without getting far from their place of birth (e.g., Verpoorte 2006), or they may have died quite far from it after a lifetime of moving very little. If by mobility we mean the area used by *individuals* over their lifetime, the direct (isotopic) evidence we have for such mobility (e.g., Richards et al. 2008; Moncel et al. 2019; Wißing et al. 2019; Nava et al. 2020) is inconclusive, perhaps simply because mobility differed across different contexts (e.g., at Spy and Goyet, or at Fumane and Riparo Broion – see Wißing et al. 2019 and Nava et al. 2020 respectively). The observed limits on maximum toolstone transfer distances may hint at upper limits to such mobility, but they may just as well reflect instead a limited capacity (or willingness) to carry the same materials for long periods (i.e., may reflect mobile toolkit turnover – see, e.g., Brantingham 2003). If, on the other hand, mobility is considered in terms of the frequency of residential moves, we can say that at times residence appears to have amounted to a few days at most (e.g., Payre level F – Moncel et al. 2019), while at others (e.g., Payre level Gb – Moncel et al. 2019) it seems to have been longer, although what that means in terms of weeks or months is seldom specified. Residence time is nevertheless critical for interpreting long-distance transfers of materials thought to have been carried in mobile toolkits, since it affects the number of residential moves such materials may be expected to survive before discard (see, e.g., Cole 2002).

c. *territory*: Another concept of critical relevance whose meaning is seldom clarified is that of "territory". Whose territory? As already noted above (see section 1.3.3.2), "tribal" and "band" territories are sometimes used almost interchangeably (e.g., Raynal et al. 2012), and there is a widespread and often implicit assumption that archaeological raw materials within a given assemblage reflect the use of the environment by a discrete group of individuals (e.g., Moncel et al. 2019) who do not regularly move to and from other such groups transporting stone. This assumption is not well-supported by ethnographic data (the composition of hunter-gatherer bands is fluid – see, e.g., Haviland et al. 2013), nor is it normally justified on other grounds. Is the presence of distant raw materials informative with regards to the maximal size of band home ranges, mating networks, or perhaps something else?

The problem is not that we lack a universal definition for these terms, or some universal theoretical framework for interpreting the data – the problem is that often the complexities and the challenges these terms pose are not discussed or acknowledged, and that data is typically not reported in a way that enables overcoming these issues.

Data collection and reporting: Data presented in provenance studies is often incomplete. For instance, information is often given on the nearest possible geological source of an archaeologically represented raw material type, but seldom for potential alternatives, the *assumption* being that such nearest sources reflected actual procurement locations. However, this assumption can be wrong if those alternatives differ in terms of properties that would have influenced procurement decisions (e.g., extent of exposure, ease of extraction, nodule shape), or if continued use temporarily depleted the supply of easily collectable rocks at the nearest source (see, e.g., Luedtke 1976). Many studies (e.g., Spinapolice 2012) also focus on maximum procurement distances, and consequently under-report the location and characteristics of potential sources located closer to the site, often simply stating that certain percentages of materials are "local" or "semi-local." This effectively reduces the resolution of the data, making it very difficult to apply or explore alternative interpretive frameworks.

Inescapable outdated interpretive frameworks: The under-reporting of basic provenance data and the problematic use of key terminology have made it difficult to move beyond the earliest interpretive frameworks. Thus, predominantly "local" raw material procurement continues to be discussed as a feature of the Middle Palaeolithic record as if no meaningful differences in landscape exploitation exist between sites provisioned exclusively with rocks available within a few meters and those provisioned primarily from sources found only at several kilometers (but less than, say, 12) from a site, despite the presence of workable materials nearby (e.g., the Bau de l'Aubesier, or La Combette, in southeastern France). Provenance data also continues to be discussed in terms of Binford's binary alternatives (e.g., curated versus expedient technologies, embedded versus direct procurement, collector versus forager settlement systems) as if these exhausted all possibilities. Yet the fact that virtually any assemblage can be made to fit into Binford's schemas is a weakness, not a strength (see Popper 1963). Aside from this, central-place foraging models (e.g., Kelly 1995) continue to strongly influence interpretation, despite the fact that they were developed on the basis of modern hunter-gatherers whose foraging habits, including division of labour (e.g., Kuhn and Stiner 2006; but see Henry et al. 2014) and the nature of the exploited resources, are likely fundamentally different from those of Neanderthals. For instance, the majority of the evidence points to Neanderthals having had a narrower diet and relying primarily on mobile terrestrial resources (e.g., Stiner 2013; Power 2019), whereas the majority of the food consumed by most ethnographically documented foragers consists of gathered, relatively stationary resources, or are of aquatic origin (e.g., Kelly 1995; Marlowe 2005). In short, few current approaches allow the data to speak for themselves (exceptions include Wilson and Browne 2011; Frahm et al. 2016), and few allow for the possibility that Neanderthals may have processed information just as competently, but differently, from us, without assuming a unilinear development of intelligence and broader cognition.

4 Methodology

4.1 Agent-based modeling:

The preceding discussion highlights the need to examine and develop alternative frameworks for interpreting provenance data which minimize assumptions, are internally coherent and consistent, employ explicitly and rigorously defined terminology, and are capable of generating hypotheses which can be unambiguously rejected. Agent-based models (ABMs) fit these criteria well. Such models, which have a long history of archaeological application (e.g., Lake 2015), enable the study of complex patterns that emerge from simple and clearly defined low-level interactions between goal-oriented autonomous agents and their environments (e.g., Bonabeau 2002). They require explicit and formal definition of all included behavioural rules and parameters, as well as careful consideration of overall model mechanics. AMBs can be used to study the systemic effects of changes in individual model components, and therefore to formulate a clear set of expectations of what may be expected under modelled conditions, and *why*.

Neutral agent-based models provide a particularly promising starting point in the development of an alternative interpretive framework based on computer simulations because they aim to be as simple as possible both in terms of their underlying assumptions – all modelled processes are either stochastic or constant – and in terms of the number and nature of included variables and parameters. Unfortunately, the quest for ultimate simplicity renders these models highly abstract, and as a result they a) can be difficult to interpret in terms of real-world relevance or applicability, and b) run the risk of unwittingly simulating impossible realities. Moreover, it has long been noted that specifying parameters for such models is notoriously difficult (e.g., Gotelli and McGill 2006) and that fiddling with these can artificially result in patterns that resemble real observations (Enquist et al. 2002). Due partly to this, such models have so far seen very limited adoption and have had minimal impact on provenance studies.

To overcome these issues, in this thesis I propose, implement, and test a minimally realistic agent-based model of raw material management (Chapter 5). As the term is used here (c.f., Plagányi 2007), a minimally realistic model (hereinafter, MRM) is one that seeks to bridge the gap between abstract neutral models and models which aim to emulate the past. In effect, an MRM seeks to be the simplest model (i.e., with the fewest variables or processes) that can generate patterns which are quantitatively comparable and compatible with archaeological observations (i.e., fit within the basic observed constraints such as assemblage size) in the absence of a given mechanism (e.g., selective land use), using real-world units (e.g., grams of stone), and postulating logically consistent behaviours and parameter settings that, based on our current state of knowledge, have a reasonable *a priori* probability of having been true in the target temporal and geographic context, and given the nature of the employed units and chosen modelling scale. Therefore, as envisioned here, an MRM is necessarily both spatially and behaviourally explicit. It should be noted that MRMs are not well-suited for all tasks; they are best seen as virtual laboratories, to borrow a phrase from Premo (e.g., Premo 2010), where assumptions can be tested and aspects of the record which are at present unknowable can be explored so as to generate clear hypotheses about the past.

4.2 Local resource selection: a network model

In this thesis I supplement the MRM approach discussed above with a novel method for investigating raw material resource selection at sites where neutral expectations (e.g., Brantingham 2003 and

Chapter 3) are clearly contradicted by the available data, as is the case with the Bau de l'Aubesier (hereinafter, the Bau - see Chapter 2 and Chapter 4).

Typically, the issue of resource selection is approached, at an assemblage level, through a comparison of environmental resource availability and degrees of archaeological representation, as well as through an examination of technological parameters thought to reflect preferences, such as more intense maintenance or reduction of specific raw material types. At the Bau de l'Aubesier resource selection has been previously investigated by means of a more complex approach based on the application of GLMs, or generalized linear models (Browne and Wilson 2011; Wilson and Browne 2014). The advantage of such models, which have proven to be a fruitful avenue of research not only at the Bau and elsewhere as well (e.g., La Combette – Wilson et al. 2018), is that they enable the relative influence of multiple predictors to be examined simultaneously and in relation to each other. They also allow for the attractiveness of individual resources to be quantified from a perspective that approaches that of the hominins who used them. This, of course, is very helpful in the context of agent-based simulations, since it provides a simple way of specifying relative probabilities of selection for resources an agent may be evaluating as procurement options. However, such models are limited in their ability to incorporate or account for the possible influence of the spatial configuration of sources, shown in Chapter 3 to have a significant effect on their degree of utilization even under an entirely neutral scenario; they are also limited in their ability to explain the lack of exploitation of resources with intermediary attractiveness values.

In this thesis I therefore develop an approach to local resource selection which builds upon previous efforts while addressing some of their limitations. While it is applied specifically to the Bau de l'Aubesier, the proposed method, which enables *testing* of hypotheses premised on cost/benefit optimization, is applicable to other contexts as well. As discussed in detail in Chapter 4, it involves conceptualizing individual raw material sources as nodes in an edge- and node-weighted network of possible procurement alternatives, with edge weights corresponding to minimum travel times between nodes along least-cost paths, and node weights corresponding to a composite measure of source characteristics (e.g., raw material quality, extent of exposure). For each node in this network – that is, from the perspective of each source - the viability of procuring materials from all available alternatives, including the source itself, is determined by quantifying, using selection criteria empirically derived based on a generalized linear model, the caliper of each possible procurement path that passes through a source and ends at the site.

An advantage of this approach is that it allows for the identification of optimal exploitation alternatives for a given site while fully accounting for the presence of competing alternatives, and without assuming that the closest source of a material will have been used. A related advantage is that it allows for the identification of sources expected to have been avoided by virtue of being sub-optimal exploitation targets. This, in turn, allows for the testing of hypotheses pertaining to navigational abilities and degrees of landscape knowledge. Finally, the method provides a unique advantage in the context of an MRM that considers residential mobility (Chapter 5), since it substantially reduces the source dataset for any given site, real or simulated, based solely on archaeologically observed criteria.

5 Data used in this Thesis

5.1 Simulation data:

A substantial portion of this thesis (Chapters 3 and 5) involves the analysis of virtual assemblages generated through computer simulations. These assemblages represent spatial samples of discard records created by simulated agents at a regional scale over timeframes that vary according to the specific research goals being pursued, and which can correspond to either actual archaeological sites or hypothetical ones. They consist of aggregates of raw material units with a known history of procurement, transport, and discard, originally collected at locations that represent either real sources (Chapter 5) or randomly placed hypothetical ones (Chapter 3).

5.2 Archaeological data:

The analyses presented in Chapters 4 and 5 are based on previously published data on lithic resource exploitation at the French Middle Palaeolithic site of the Bau de l'Aubesier (Vaucluse, southeastern France). This rockshelter, hereinafter referred to as "the Bau" and discussed at length in Chapter 2, has yielded a complex and rich archaeological sequence some 13 m thick and deposited over the course of roughly 100,000 years or more (≥200 kya to ≤ 100 kya). It is found in an area of variable topography that has not experienced major geomorphological changes over the last 200,000 years and was never glaciated. The region surrounding the site has also been thoroughly investigated for the purposes of lithic sourcing by Lucy Wilson who, over the course of more than 25 years, has located and systematically documented 350 naturally occurring primary and secondary deposits of knappable rocks available within ca. 40 km of the site, most of which appear to have been unexploited by the site's inhabitants.

The total number of lithics recovered from the partially excavated deposits amounts to at least 85,000 (de Lumley-Woodyear 1969; Texier 2004). Of these, 40,770 pieces originating from throughout the sequence have been analyzed by Wilson for provenance purposes. Although alternation such as patination and burning prevented adequate raw material characterization for most lithics, 15,674 artifacts could nevertheless be matched to a minimum of 17 and a maximum of 101 possible procurement locations (Wilson and Browne 2014). The available evidence indicates that these sourced artifacts are representative of the overall artifact sample, both in terms of the variation in raw material types and in terms of their coverage of the Bau sequence.

Previous studies of the Bau dataset also indicate that materials were selectively procured from sources located within a relatively narrow interval of 8 to 13 km from the site. While this is still within the "extended foraging radius" that may be covered by hunter-gatherers during occasional daily forays (e.g., Mellars 1996), it certainly deviates from the general trend of provisioning sites from sources found within 5 km or so. There are many exceptions to that trend, however, and from a variety of regions and site types: at the nearby La Combette, for instance, 55% of the materials were procured from sources located at more than 18 km from (Wilson et al. 2018). At the Iberian site of Abric Romani (level M), 81% of the materials are reported to have been collected from sources located 5-10 km away (Fernandez-Laso et al. 2011; see also de la Torre et al. 2013), a situation similar to that seen at Payre in France (Daffara et al. 2019; see also Santagata et al. 2017: 476; Moncel et al. 2019). At Axlor (Spain), the majority of lithics are made of stone likely collected at 15-30 km from the site (de la Torre et al. 2013), like at Las Fuentes de San Cristobal, also in Spain, where most of the assemblage consists of lithics procured at 9-25 km (Garcia-Anton et al. 2011). At Karabi Tamchin in Crimea, the predominant use of materials collected at ca. 25 km from the site is also attested (Yevtushenko et al. 2003; Burke 2006), and at Wallertheim (Germany) Adler (2003) documents the dominant use of materials found at 6 km from the site. There are also far more striking examples: at the Italian site of Grotta dei Giganti, for instance, half of the materials were reportedly procured from sources located at more than 100 km (Spinapolice 2012).

Given the above, the Bau was selected for the purposes of this thesis because:

a) the present-day availability of lithic resources in the area is well-known, and it can be considered to be representative of what could have been exploited during the deposition of the Middle Palaeolithic layers at the site (this assumption is tested in Chapter 4).
b) raw material sources are known over an area large enough to allow for a realistic modelling of residential mobility.
c) The available archaeological data is comprehensive and covers a very long time-span, increasing confidence in the proposition that unexploited sources were intentionally ignored or avoided rather than simply unknown or unavailable to hominins inhabiting the site, and therefore allowing for hypotheses regarding landscape knowledge and navigational abilities to be tested (see 1.4.2 above).
d) It provides an opportunity to explore an atypical case of "local" raw material exploitation which could in principle reflect either the regular use of large (i.e., 8 – 13 km) daily exploitation territories or site provisioning in the context of residential mobility within small (i.e., 8 - 13 km) home ranges.

5.3 Geospatial data:

The geospatial data used in this thesis (Chapters 4 and 5) consist of: a) postprocessed Shuttle Radar Topography Mission (SRTM) digital elevation models (DEMs) supplied by the International Center for Tropical Agriculture (Jarvis et al. 2008), and b) point source coordinates for raw material sources supplied by Lucy Wilson. SRTM data are freely available not only for the region but also globally, and their adequacy for the type of route calculations required in the context of this work (Chapter 4) has been demonstrated, comparing favourably with higher resolution datasets available for the targeted area (Browne and Wilson 2013). Point source coordinates, on the other hand, are adequate given the resolution of the SRTM data and the size of the study region, which is defined on the basis of the available sources and covers roughly 100x100 km. Source extents do exceed the size of the raster cells by a factor of up to two in approximately 30% of cases, and a few sources represent linear features, but this is not expected to result in notable inaccuracies.

6 Outline of Thesis Chapters

6.1 Chapter 2: An overview of the French Middle Palaeolithic site of the Bau de l'Aubesier

This chapter presents an overview of the Bau de l'Aubesier based on an extensive review of the available literature. My sole aim in this section is to provide relevant context for the interpretation of the analyses presented in Chapters 4 and 5.

6.2 Chapter 3: Re-examining basic assumptions through a systematic re-evaluation of Brantingham's neutral model of raw material procurement

In 2003 Jeffrey Brantingham published a neutral model of lithic procurement which sought to simulate archaeological raw material variability in the absence of any optimization strategies in the acquisition, use, transport, and discard of lithic materials. On the basis of similarities between model-generated and archaeologically observed patterns, he concluded that said variability may not be informative with regard to past adaptation. Despite being one of the most cited lithic procurement papers from the early 2000s, and despite its profound implications, the third chapter of this thesis provides the first systematic re-assessment of the model. My aim is both to revisit Brantingham's provocative claims, and to explore the limitations and theoretical potential of neutral models more broadly.

While I demonstrate that Brantingham's original model is flawed in that it cannot produce meaningful analogues of the archaeological record, my analyses underscore the promise of agent-based neutral models as alternative starting points for the interpretation of lithic raw material variability and, more generally, as exploratory tools. On the basis of a revised model, Chapter 3 outlines a new set of expectations for what such variability should look like under neutral conditions, and highlights some aspects of provenance data that should be reported so as to maximize inferential potential. On the other hand, my results also underscore the need to maintain a minimal degree of realism in model parameter estimation, simulation lengths, and in the implementation of behaviours that can ensure the survivability of the agents.

6.3 Chapter 4: A network model of local resource selection for evaluating landscape knowledge, navigation, and foraging extents at the Bau de l'Aubesier

This chapter introduces a novel approach for determining the likely extents of the foraging areas around archaeological sites on the basis of lithic provenance data. The approach is designed to test hypotheses of Neanderthal mobility, landscape knowledge, navigational abilities, and resource selection criteria without relying on ethnographic analogies, Neanderthal-specific energetic and/or biomechanical estimates (e.g., Verpoorte 2006), or other lines of evidence aside from the raw material source data themselves. As noted in the methodology section above (see section 1.4.2), this approach is premised on a conceptualization of raw material sources as nodes in an edge- and node-weighted network of plausible procurement alternatives and an evaluation of optimal procurement paths based on archaeologically evidenced selection criteria determined using a generalized linear model (GLM).

The approach is applied to the Bau de l'Aubesier to explain why large majority of available sources appear to have been systematically ignored over a period of some 100,000 years despite many yielding good materials in relatively close proximity to the site. The results demonstrate that the situation at the Bau is not explainable by substantial changes to the lithic resource landscape (see e.g., Dibble 1991) or simple chance; instead, it is consistent with a pragmatic strategy of lithic resource exploitation over a large area extending some 2.5 - 3.5 hours from the site, purposeful but largely embedded in other activities, and underpinned by excellent navigational skills and knowledge of the region. The results are also consistent with a relatively uniform utilization of the landscape by the site's inhabitants.

6.4 Chapter 5: Exploring home ranges and non-local procurement through a minimally realistic model of raw material management at the Bau de l'Aubesier

The impact of residential mobility on archaeological raw material variability is poorly understood, at least in quantitative terms. What percentage of materials found at one site can we expect to have been collected by hominins while residing at other sites? What is the likelihood that these materials were collected from the same geological sources, therefore appearing to be "local"? How many residential moves can we reasonably expect raw materials to have survived in mobile toolkits? Can such transported materials be distinguished from recycled implements transferred between sites by unrelated groups? How does this impact interpretations of territory sizes on the basis of maximum transfer distances? Chapter 5 answers such questions by integrating the local resource procurement model developed in Chapter 4 into a regional-scale agent-based simulation of lithic raw material management. The novel simulation framework introduced in this chapter is minimally realistic (see section 1.4.1 above) and is developed based on insights gained from the re-examination of Brantingham's neutral model discussed in Chapter 3. It is applied to the Bau in order to explore assemblage variability and the extent of the territories where raw material exploitation is consistent with the resource selection criteria evidenced at the site, in order to better understand the scale of mobility and land use strategies employed by hominins who resided there (however briefly).

The results presented in this chapter reaffirm the conclusions of Chapter 4, particularly with regards to the navigational skills, degree of landscape knowledge, and optimizing resource exploitation strategies evidenced in the record preserved at the Bau. Overall, I find that the explanation proposed in Chapter 4 for why a majority of regional sources were not exploited by the inhabitants of the site holds even if the effects of residential mobility are factored in. These results do leave open the possibility that the territories regularly used by hominins while residing at the Bau (i.e., daily exploitation territories) may perhaps not have extended quite as far as 2.5 to 3.5 hours from the site, but they also show that the Bau data are inconsistent with a regular exploitation of territories smaller than seen in modern hunter-gatherers (cf., Verpoorte 2006). Beyond this, the analyses presented in Chapter 5 enable a series of predictions to be made regarding the expected assemblage raw material composition for any contemporaneous site in the region and highlight areas of compatibility with data available from the Bau.

6.5 Chapter 6: Conclusions

This chapter provides a synthetic overview of the main theoretical and practical contributions of this thesis, outlining some promising future research directions.

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