The Band Model: contextualising Middle and Upper Palaeolithic sociality within a fission-fusion framework

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The Band Model: contextualising Middle and Upper Palaeolithic sociality within a fission-fusion framework

David Thomas Gregory Clinnick

Abstract

Since William King's first description of the species *Homo neanderthalensis* (1864), assessments of Neanderthal social behaviour have been biased by the assumption that this was a species of simian brutes. However, in recent years, genetic, palaeoanthropological, and archaeological findings have significantly undermined the assumption of specific biological and behavioural differences between Neanderthals and AMHs (Green et al. 2010; Reich et al. 2010; Hammer et al 2011; Mendez et al. 2013; Trinkaus 2011; Zilhão et al. 2010; Henry et al. 2011; Pike et al. 2012; Peresani et al. 2013; Rodriguez-Vidal et al. 2014). Despite these findings, trait-list arguments still dominate research paradigms concerning the sociobehavioural capacities of Neanderthals and AMHs.

The current state of the human material, paleontological, and paleogenetic records necessitate a more robust theoretical foundation than the one that trait-list models provide (Barton et al. 2011). A socio-ecological approach based within fission-fusion studies can provide robust test hypotheses with the potential to elucidate the evolution of modern social complexity. Following this direction, this thesis adapts the band model of hunter-gatherer sociality (Layton and O'Hara 2010; Layton et al. 2012) to archaeological investigation. The results of this approach both demonstrate the applicability of the band model to Palaeolithic research and highly suggest that Neanderthals and anatomically modern humans shared a comparable fission-fusion sociality.

The Band Model

Contextualising Middle and Upper Palaeolithic sociality within a fission-fusion framework

David Thomas Gregory Clinnick

A thesis presented for the degree of
Doctor of Philosophy
Department of Archaeology
University of Durham
UK
2015

Table of Contents

Table of Figures

Table of tables

Statement of Declaration

I, the author of this thesis, declare that this thesis and the work presented herein are my own. No part of the work has been submitted in support of an application for any other degree in this university or any other. Where other sources of information have been used, they have been acknowledged.

Signature:

David Thomas Gregory Clinnick

Statement of Copyright

Acknowledgements

First and foremost, I must acknowledge the support and patience of my wife, Ann Clinnick. I never let anything I have written that is of importance to me leave my desk without her reading it first. More importantly, if it were not for her, I would never have pursued higher education. I must also thank my young children, Tristan and Aurelia, for their understanding and love, which has motivated me so much over these past years. Beyond my family, I must thank James Walker for his friendship and shared interest in all things academic and beyond.

There are many others who I must acknowledge and will do so in the final submission if this thesis is successful. For now, however, I would like to thank my supervisors, Mark White and Peter Rowley-Conwy, and Christian Tryon who was my academic sponsor/adviser during my visiting fellowship at Harvard in 2014.

And the stones began (who would believe it
without the testimony of antiquity?)
to lose their hardness, slowly softening
and assuming shapes. When they had grown and taken on
a milder nature, a certain resemblance
to human form began to be discernible,
not well defined, but like roughed-out statues.

Ovid, *Metamorphosis*, I.417-423

CHAPTER 1

Introduction

Introduction

Recent studies have demonstrated that at least two archaic hominin populations contributed directly to the genetic makeup of modern humans outside of sub-Saharan Africa (Green et al. 2010; Reich et al. 2010; Hammer et al 2011; Mendez et al. 2013). Other research has undermined long-held assumptions about behavioural (Zilhão et al. 2010; Henry et al. 2011; Pike et al. 2012; Peresani et al. 2013; Rodriguez-Vidal et al. 2014) and life-history (Trinkaus 2011) differences between archaic hominins and anatomically modern humans. These findings question the established Out-of-Africa model that places the origin of modern behaviour and extant human populations in either the Middle Stone Age or Later Stone Age of Africa.

The preponderance of trait-list derived test criteria (Table **1**) means that the justification for interpreting the modernness of certain sub-phases of the Middle Stone Age (MSA) as well as some material derived from late Middle Palaeolithic contexts is dependent on their supposed similarity to the European Upper Palaeolithic (McBrearty and Brooks 2000; Henshilwood and Marean 2003; McBrearty 2007). In fact, Barton et al. (2011) argue that regardless of their permutation the majority of behavioural modernity models (BMMs) are constructed around traits lists that at best lack theoretical justification. They suggest that the validity of a BMM depends on it being grounded in ethnographically observed syntheses of human behaviour and sociality. Taken altogether, the lack of concord between currently accepted evolutionary models and empirical evidence produces a convoluted and inconsistent narrative of human evolution.

Modern Archaeological Traits
Standardised artefacts
High rates of chronological diversity in technological systems
Spatial organization of site surfaces
Long distance lithic sourcing
Ritualised burials
Ochre use
Worked bone and antler
Blade technology
Large mammal exploitation
Increased diet breadth

Table 1. Traits-list. Compiled from Klein (2008, 270 table 1) and Henshilwood and Marean (2003, 628 table 1).

The current state of the human material, paleontological, and paleogenetic records necessitate a more parsimonious solution. A socio-ecological approach based within fission-fusion studies can provide robust test hypotheses with the potential to elucidate the evolution of modern social complexity. This thesis follows this direction by adapting the *Band Model* of hunter-gatherer sociality (Layton and O'Hara 2010; Layton et al. 2012) to archaeological investigation.

This following sections outline the aims and objectives, test model, and outcomes of this thesis. In order to effectively convey this information and set the general tone for the structure of the thesis itself, this information has been provided under a series of headings providing the primary objectives, background information, test model, study cases, thesis structure and chapter summations, and thesis results.

Aims and objectives

The principle objective of this thesis is to adapt the *band model* to archaeological investigation and thus enable an analysis of late Neanderthal and early anatomically modern human (AMH) sociality in western Eurasia during the Middle to Upper Palaeolithic transition (MP/UP transition). A central concern of this thesis is to shift the interpretation of the evolution of modern cognition away from a "traits-list" argument, which has been seen as holding up the European Upper Palaeolithic as the "yardstick by which human accomplishments must be measured" (McBrearty 2007, 145). Therefore, a primary aim of this study is to overcome *posteriori* inferences about the adaptive functionality of particular aspects of the material record and instead examine the material record within an analytical paradigm deferential to observed patterns of hunter-gatherer, fission-fusion behaviour.

To this end, I have developed an analytical framework based on a synthesis of empirical observations of hunter-gatherer sociality (Layton and O'Hara 2010) to detect and interpret sociality patterns in the material record of the Late Pleistocene, allowing an examination of Neanderthal and AMH adaptability to changing ecological circumstances. I accomplish this through investigating lithic sourcing, prey selection and environmental patterns of Mousterian, Chatelperronian, Protoaurignacian, Early Aurignacian, Gravettian, and Magdalenian associated contexts.

Background

Fission-fusion studies in primatology are concerned with the complex social behaviours expressed by some primate species in which segments of a community split into smaller subunits (Amici et al. 2008, 1415) to enable the exploitation of resources and defuse intra-group stress. In "Fission-Fusion Dynamics: New Research Frameworks," Amici et al. propose that "the term 'fission-fusion dynamics' be used" to describe the complexity and degree to which a species' social behaviour demonstrates flexibility "in spatial cohesion and individual membership in a group over time" (2008, 628). Baboons, geladas, chimpanzees, and humans are species that demonstrate a high degree of fission-fusion dynamics through the splitting and converging of subgroups within communities to better exploit resources within a given environment (ibid, 627). A high fission-fusion dynamic places acute social pressure on communities to "reestablish relationships and resolve uncertainties" as agents become more greatly bracketed both spatially and temporally (ibid, 632).

Chimpanzees express a "high degree of fission-fusion dynamics but also a very high level of cooperation and affiliation within communities" (Aureli et al. 2008, 638). Both humans and chimpanzees present a gendering of labour tasks, but humans are unique in that this division of labour creates mutual dependency (Layton and O'Hara 2010, 86). Humans and chimpanzees also actively hunt. However, chimpanzees will share meat with select allies whereas humans are unique in that they pool resources together at a central camp for redistribution among community members. Layton and O'Hara in "Human Social Evolution: A Comparison of Hunter-gatherer and Chimpanzee Social Organization" (ibid) analyse hunter-gatherer and chimpanzee communities within overlapping ecological zones, noting that a behavioural commonality of fissioning and fusing of subunits within the communities of both species exists to mediate "ecological constraints" (2010, 86). They argue that shifts toward higher levels of carnivory in the human dietary regime have led to different social specializations within the human and pongid clades (ibid). Mutual dependence of gendered roles and resource pooling to a central camp are behaviours that seem to be part of social systems unique to humans, constituting a band sociality with more stable and longer-lasting subunits.

Layton and O'Hara (2010) and Layton et al. (2012) argue that understanding the differences in the degree of fission-fusion dynamism, the division or fissioning of communities to perform task-specific activities, witnessed between extant hunter-gatherers and troops of *P. troglodytes* may help to clarify the effect of encephalization on the evolution of behavioural modernity. Dunbar and Shultz (2007) note that total brain volume and not the structure of the brain itself accounts for energetic cost, but brain "structure" i.e. neocortical mass influences social and general intelligence.

The suggestion that a brain volume near modern expectations emerged during the Middle Pleistocene (Rightmire 2004) implies that the hominin clade has faced a similar if not the same energetic demand from *H. heidelbergensis* to *H. sapiens*. Given the high, energetic cost of the modern brain at 14.6 watts (Aiello and Wheeler 1995), the lack of evidence for selection on either anatomically modern human or Neanderthal craniometrics (Weaver et al. 2007) negates the assumption that there was an adaptation in the morphology of the human brain to overcome the energetic constraints of encephalization. This is further supported by observations that indicate that allometric scaling best accounts for the differences in the neocortices of modern humans and pongids (Herculano-Houzel et al. 2007; Herculano-Houzel 2012), and despite the fact that there are differences in the neural loading of different mammalian species, this does not appear to be the case between humans and pongids (Buckner and Krienen 2013).

The expensive tissue hypothesis (Aiello and Dunbar 1993; Leonard and Robertson 1994; Aiello and Wheeler 1995; Aiello 1997; Milton 2003) helps to explain the energetic effects and thus dietary shifts anticipated due to encephalization. The overall basal metabolic rate (BMR) of extant humans is consistent with anticipated energetic consumption for a mammal of equivalent mass. However, the energetic demand of the modern brain is far greater than that of even our closest living relative [human brain BMR = 14.6 watts (Aiello and Wheeler 1995, 200) whereas *P. troglodytes* brain BMR = 2.6 watts]. Observing that the extant human gastro-intestinal tract is 60% of what would be predicted for a primate of equivalent mass, Aiello and Wheeler (1995) posit that encephalization has been paired with a decrease in overall splanchnic organ mass as an evolutionary mechanism to conserve energetic cost of the human physiology. The reduction in the human digestive tract would have shifted the dietary demand of the human clade toward high quality foods and thus increased carnivory.

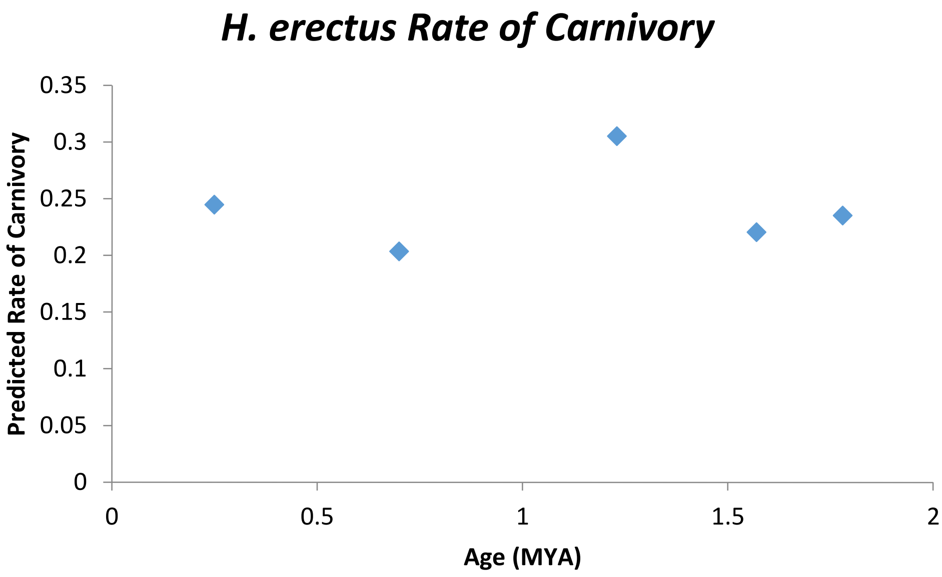


Figure 1. Predictions for the rate of *H. erectus* carnivory (formula: $A=lnE(4.1*10^{\wedge-5})E$). *H. erectus* sample population from Aiello and Dunbar 1993, 188-9 table 1.

Layton and O'Hara (2010) note that ethnographic evidence demonstrates a high protein quotient in the diet of hunter-gatherer communities. The average rate of carnivory presented by hunter-gatherers is 41% of total dietary exploitation (Layton and O'Hara 2010, 92 table 5.2). Assuming that there is a compounding rate of protein increase in relation to encephalization, a very rough formula can be produced to predict the rate of carnivory specific to hominid demes: $A=lnE(4.1 \times 10^{-5})E$. This formula produces an anticipated rate of dietary protein for *P. troglodytes* at 9%, falling within observed rates at 13% to 2% (Milton 2003:3886). Utilizing this formula (Figure

1), the predicted rate of carnivory at 24% for *H. erectus* (average brain = $870mm^3$ derived from Aiello and Dunbar 1993:188-9 table 1) is almost half of that observed amongst hunter-gatherers. This suggests that there was a major shift in the hominin dietary regime from *H. erectus* to the last common ancestor of Neanderthals, Denisovans and modern humans.

Layton and O'Hara (2010) observe that the increase in human carnivory has had a direct impact on human population density and thus social structure. Due to the reduction in carrying capacity caused by a carnivorous exploitation regime, within overlapping ecological ranges, hunter-gatherers can only maintain a population density of 0.31 persons per km^2 whereas chimpanzees can maintain a population density of 2.5 per km^2 (ibid). This suggests that there have been different costs both energetically and socially for *P. troglodytes*, *H. erectus*, and hominins with a modern brain mass.

Plotting the observed points of brain mass and population density on a linear curve for hunter-gatherers and *P. troglodytes* gives a formula for the curve as $y = -0.002227874(x) + 3.392$. Plotting *H. erectus* on this curve gives an anticipated population density of about 1.5 agents per km^2 (Figure **2**). If this curve were imagined as a hypothetical environment that *P. troglodytes*, *H. erectus*, and modern humans could exploit suggests a significant decrease in population densities throughout the course of human evolution. Under this assumption, it would appear that *H. erectus* was able to maintain a population density five times that of modern hunter-gatherers due to their ability to exploit lower tier, caloric resources.

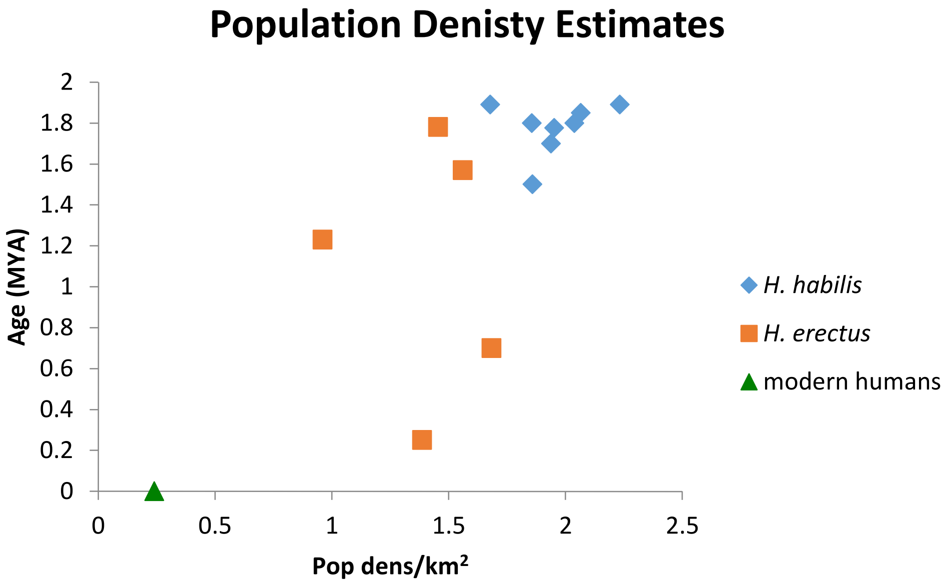


Figure 2. Population density estimates for *H. habilis*, *H. erectus*, and modern humans. Data from Aiello and Dunbar 1993, 188-9 table 1.

This suggests that the importance of modern social intelligence hinges on the ability to maintain community cohesion at a population density below 1 person per km^2. This may provide an important addition to Dunbar's (1993) model of the evolution of complex communication systems. Perhaps, the need for symbolic language evolved not simply due to a necessity to maintain social bonds within an increasing group size, but due to an increase in the bracketing of agents in time and space. This implies that low population density resulting from the economic cost of encephalization meant that shared patterns of interaction had to have evolved, as random or chance interaction could no longer provide a functional mechanism for group cohesion and mate selection (*but see* Grove et al. (2012) for an alternative argument). Therefore, under a fission-fusion model it could be said that social *complexity* = number of agents + time and space.

Developing an integrated model

As I outlined in Band Sociality: the fission-fusion dynamics of behavioural Modernity (MA dissertation), Layton and O'Hara (2010) posit the band structure as a social unit unique to modern human sociality. Viewed within the context of fission-fusion studies, the lack of a band structure in chimpanzee society demonstrates a different social response to physiological and ecological conditions. Further, Layton and O'Hara (2010) argue that the human band should not be compared to the troop structure of chimpanzee society, but to what I described in this thesis as the *regional group*, a network of interconnected bands that usually form a dialectical as well as an endogamous body. The band model proposes that a band/regional group social structure is basal to the capacity for behavioural and cultural modernity.

The exploitative success of the band is dependent on the ability of agents to obtain a significant portion of the "diet of the community through hunted prey" (Layton and O'Hara 2010, 93). The expensive tissue hypothesis (Aiello and Dunbar 1993; Leonard and Robertson 1994; Aiello and Wheeler 1995; Aiello 1997; Milton 2003) elucidates the need for a high intake of protein in the modern human diet. As previously noted, the hypothesis posits that in compensation to increased encephalization, splanchnic organ mass reduced to conserve overall basal metabolic rate, causing a shift toward a high quality diet and thus increased carnivory (Aiello and Dunbar 1993, 211).

The increase in rates of carnivory would have been deleterious to the social cohesion and group functionality of pre-behaviourally modern hominins. High levels of carnivory would have reduced the carrying capacity of previously inhabited environs, placing agents at greater distances in both space and time. As "[e]ighty-seven percent of basal metabolic rate" in neonates is devoted solely to brain development (Milton 2003, 3891), the survivorship of dependents would have taken on greater importance to the survival of hominin communities as a whole, causing reproductive success to be placed on the group and not solely the individual or reproductive dyad.

The band model argues that the evolution of the band structure enabled humans to overcome the deleterious effect of increased carnivory by allowing the human community to fission into smaller units, the band, while still maintaining social cohesion through overlapping reciprocal networks enabled through a shared symbolic language. Layton and O'Hara note that without language, "the distinctively human form of fission-fusion society" could not exist (2010, 107).

The evolution of a modern brain mass during the middle Pleistocene is of great significance to the interpretation of a boundary for the emergence of a band sociality (Layton et al. 2012; Grove et al. 2012). The reason for this is twofold: firstly, brain size in primates correlates well with total community size (Dunbar 1992; 1995; 1996); secondly, the increase in brain size would have shifted the hominin diet toward higher tiered food resources. Both effects would have inflated the impact of hominin communities on inhabited environments, placing a selective pressure on the degree of fission-fusion dynamism. The fissioning of hominin communities into more permanent subunits, bands, would have enabled an effective diffusion of agents, minimizing ecological constraints (Figure **3**).

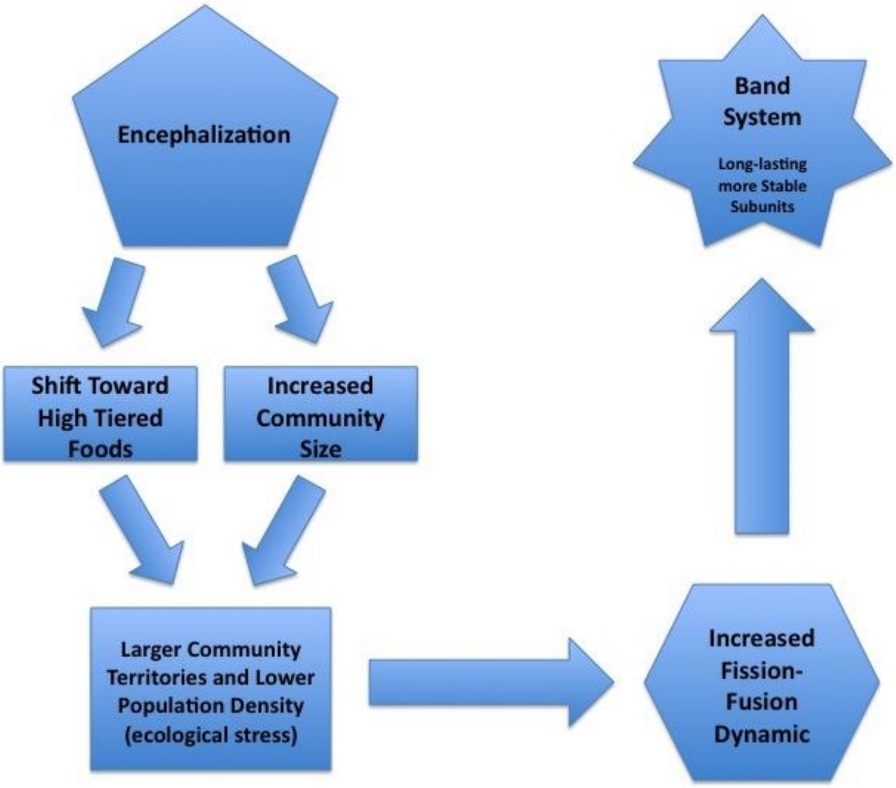


Figure 3. Effects of increased encephalization on fission-fusion sociality.

Utilizing Layton and O'Hara's band/regional group sociality template, I have built a model of community territoriality and demography incorporating methodologies developed by Smith (1992), Ambrose and Lorenz (1990), Gamble (1999), Whallon (2006), Layton et al. (2012), and Haydon (2012). The model utilizes lithic sourcing regimes at the site/occupation horizon level contextualized within environmental and subsistence patterns to determine demographic shifts and the degree to which these patterns are reflective of modern fission-fusion behaviours. Careful attention is given to how these patterns trend between technological industries and the two human species, Neanderthals and AMH. Lithic material sourcing is used as a primary proxy for determining foraging areas and interaction networks under the assumption that "[s]ite-to-source distances for stone raw material provide the best empirical estimate of the size of the physical and social landscapes" of Palaeolithic communities (Tryon and Faith 2013, 244).

The first test of the model's applicability is to determine the boundary for the emergence of a modern brain mass and the examination of potentials concerning neurological and structural differences between the brains of different hominin demes, namely *H. heidelbergensis*, *H. neanderthalensis*, and *H. sapiens*. This will test the validity of the assumption that Neanderthal and early modern human community sizes (i.e. number of agents) would have fallen within the range of extant hunter-gatherer variability. The next and most challenging test is determining network/interaction areas from the archaeological record and assessing whether the differences that occur in this regard, both between technological industries and the two species, were the result of biogenetically dependent behavioural differences, historical trajectories, or environmentally conditioned responses.

Case Studies and associated industries

The selection of survey areas was based on two criteria: they needed to include well documented sites comprising stratigraphically secure transitional horizons, and the two survey areas needed to be roughly contemporaneous to enable a more generalized examination of the social behaviours of late Neanderthals and early AMH communities in western Europe.

Study Areas and primary sites:

The original hope in the selection of the survey areas was the primary goal of comparing patterns of terminal Neanderthal behaviour with that of the first AMH colonizers of Europe. It is for this reason that I selected the French site of Les Cottés, Vienne France, and the Swabian Jura sites of Geissenklösterle and Hohle Fels (Figure **4**) under the assumption that the associated Chatelperronian occupation with the former was contemporaneous with the Aurignacian occupations of the later (Hublin et al. 2012). After my review of recent dating programs (Talamo et al. 2012), it is my contention that these occupations largely do not overlap (*see* chapters 9 and 10).

The sites were retained, nonetheless, for several important reasons: both localities can be contextualized within their specific regional contexts due to historic and contemporary archaeological testing of adjacent sites; they themselves have been subject to historic and contemporary testing, allowing for reappraisal of previously published reports; they have been subject to extensive chronometric examination (Talamo 2012; Li et al. 2013; Jacobs et al. 2015; Richter et al. 2000; Bolus and Conard 2001; Conard and Bolus 2003; Conard et al. 2003; Conard and Bolus 2006; Conard and Bolus 2008; Higham et al. 2012); they have been examined within regional contextualized patterns of raw lithic material sourcing (Burkert and Floss 2006; Primault 2003); perhaps most significantly, they present stratigraphically secure transitional sequences.

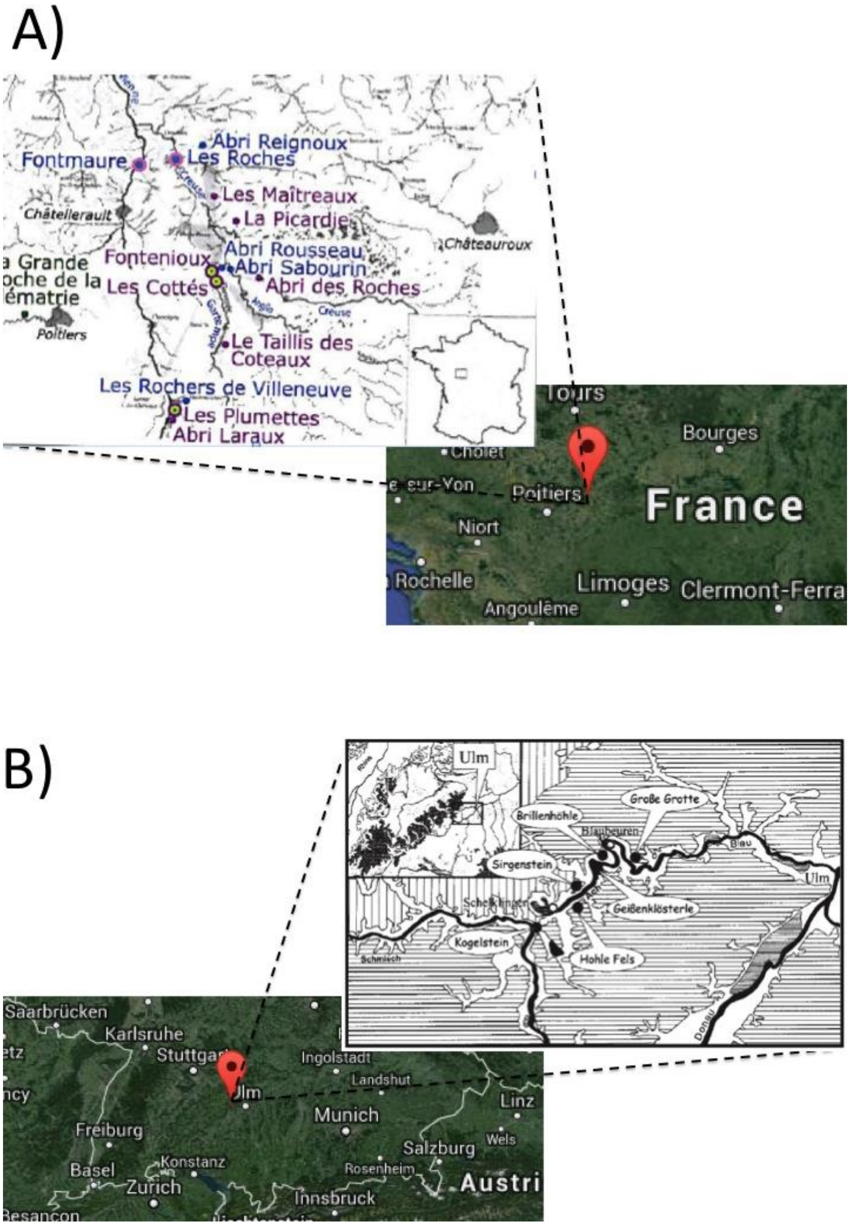


Figure 4. Location of Les Cottés, Geissenklösterle, and Hohle Fels. A) Location of Les Cottés and surrounding survey area (satellite image: TerraMetrics, Map data 2014 GeoBasis-DE/BKG (2009), Google, BCN IGN, Spain; archaeological sites detail: Soressi et al. 2010, 222 fig. 1.). B) Location of Geissenklösterle and Hohle Fels with surrounding survey area (satellite image: TerraMetrics, Map data 2014 GeoBasis-DE/BKG (2009), Google; archaeological sites detail: Münzel and Conard 2004a, 226 fig. 1).

Associated technological industries:

The archaeological dataset I examine in this thesis includes levels from the Quina Mousterian, Final Mousterian, Chatelperronian, Protoaurignacian, Aurignacian, Gravettian, and Magdalenian. The dataset is predominated by samples from the Mousterian (n = 3) and Aurignacian (n = 3) traditions. The *transitional* Chatelperronian industry falls between these two in France and northern Spain (Figure **5**). There are a few points of concern that are addressed below concerning the definition of these three traditions, their demic association, and relationship to one another.

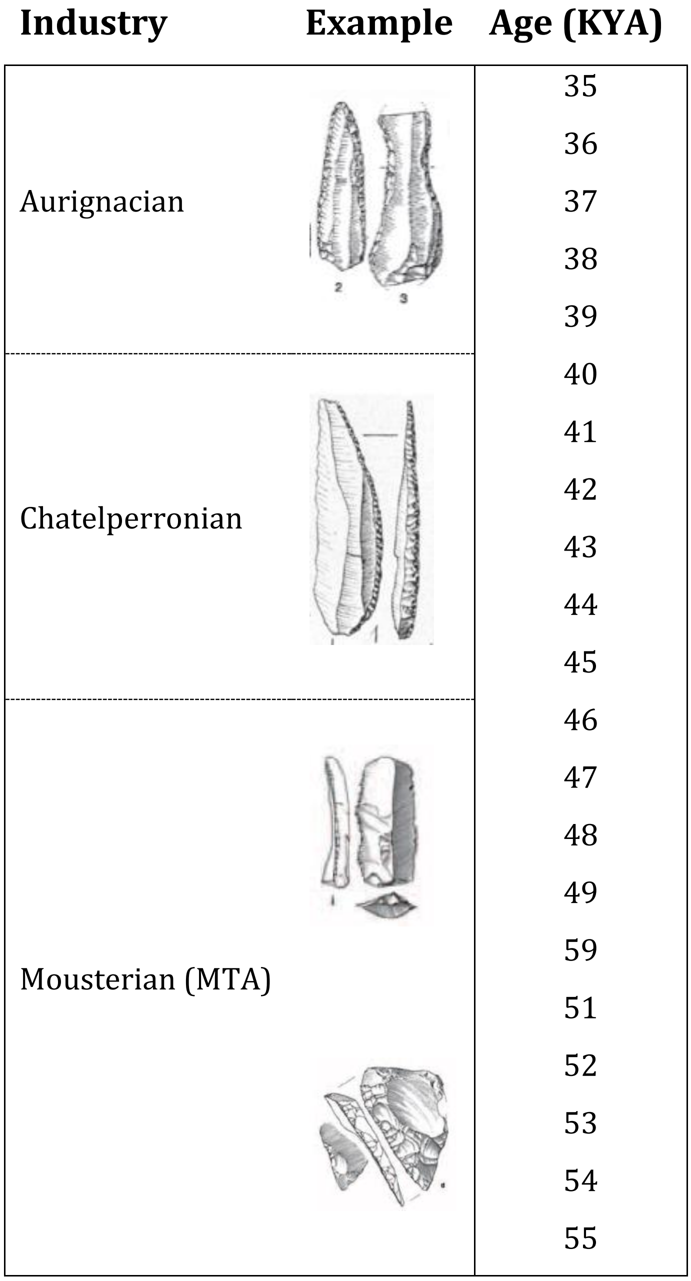


Figure 5. General chronology of MTA, Chatelperronian, and Aurignacian. Dating range from Mellars and French (2011). Mousterian image from Soressi (2005, 394 fig. 3), Chatelperronian image from Pradel (1963, 583 fig. 1), Aurignacian image from Mellars (2004a, fig. 4).

-Mousterian

Despite the fact that there is an important degree of diversity within the final Mousterian, the most basic points are that in Europe it is assumed to be solely a Neanderthal product (Conard and Bolus 2003) comprised largely of prepared core flake tools but also with a component of discoidal, bifacial, and leptolithic elements (Figure **6**).

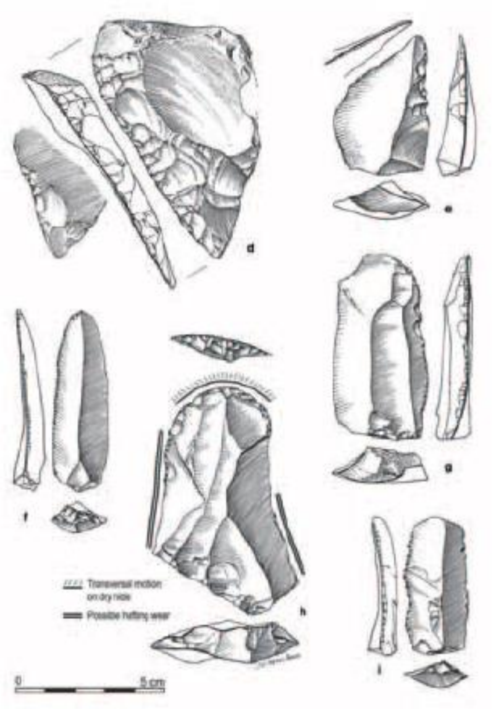


Figure 6. Typical elements of the MTA, one of the final variants of the Mousterian (Soressi 2005, 394 fig. 3).

-Chatelperronian

The Chatelperronian is characterized by the backed Chatelperronian knife type-fossil (Figure **7**), now interpreted as functioning as a lithic armature or projectile rather than strictly as a cutting or processing implement (Teyssandier et al. 2010). The industry is primarily composed of points and backed knives on wedge shaped blanks removed from prismatic cores (Figure **8**). The type-site for this industry is Grotte de Fées du Châtelperron (Zilhão et al. 2008). The discovery of modern human remains within a purported Chatelperronian horizon at Combe-Capelle led to the assumption that the Upper Palaeolithic, wholesale, was a product of anatomically modern humans, themselves new arrivals to Europe (Pradel 1966). In fact, it was held for a time that there may have been as many as three separate cultural and ethnic groups within western Europe at the time of the Middle to Upper Palaeolithic transition:

- Two AMH groups

- Combe-Capelle with a Chatelperronian/Perigordian culture
- Cro-Magnon with an Aurignacian culture
- Remnants of Neanderthal communities associated with the Mousterian culture.

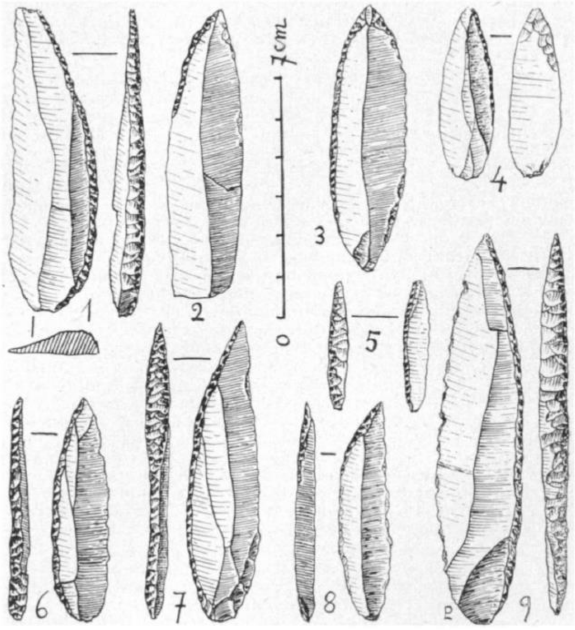


Figure 7. Chatelperronian elements from Les Cottés (Pradel 1963, 583 fig. 1).

The work of Asmus in the 1960s cast serious doubt on the stratigraphic integrity of Hauser's early 20th century excavations at Combe-Capelle, and thus, the association of the modern human remains with the Chatelperronian archaeological assemblage (Lévêque 1997, 280). With the direct dating of the Combe-Capelle remains to ~8,000RCY (radiocarbon years) (Hoffmann et al. 2011), there is little doubt about the intrusive nature of the burial.

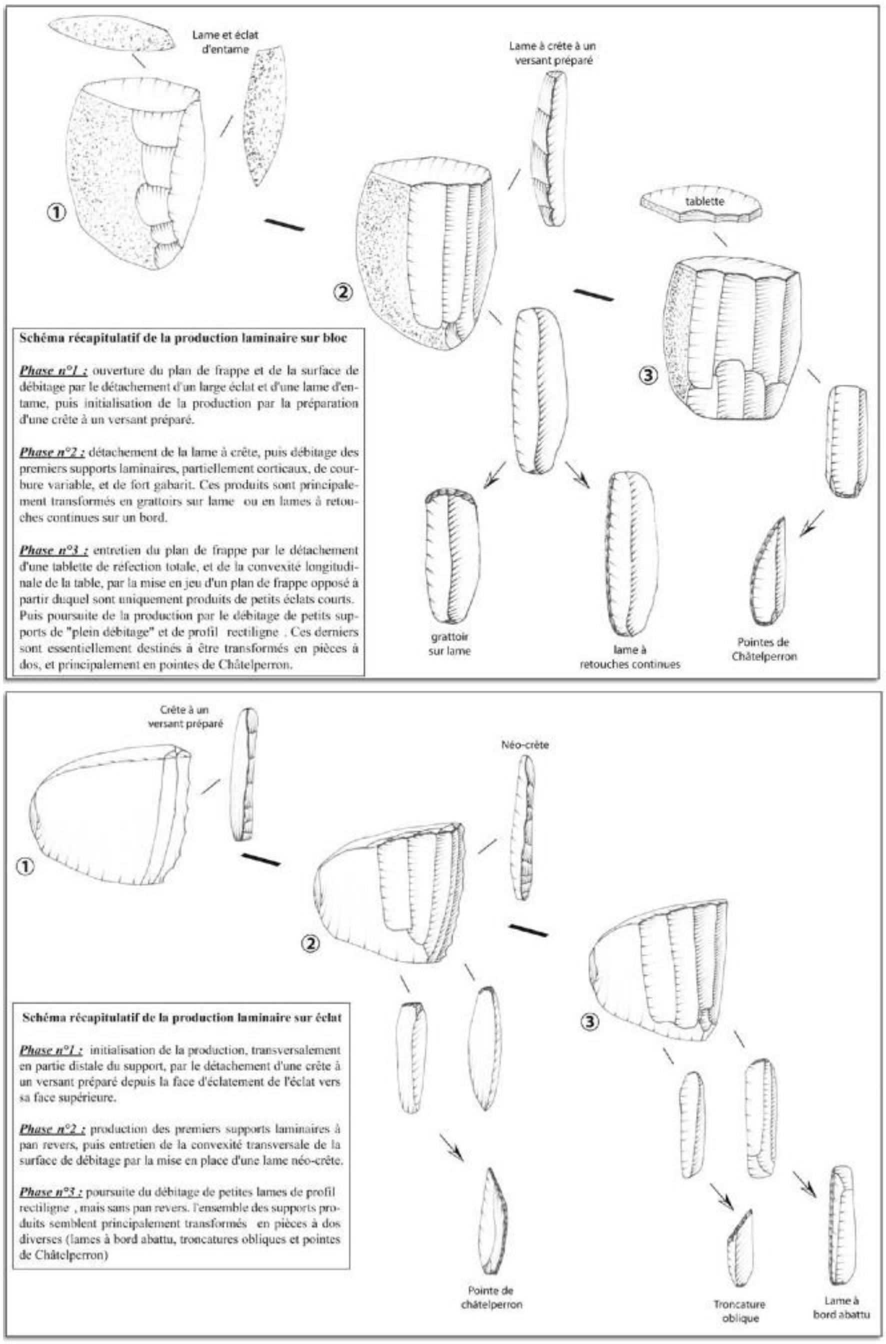


Schéma récapitulatif de la production laminaire sur bloc

Phase n°1 : ouverture du plan de frappe et de la surface de débitage par le détachement d'un large éclat et d'une lame d'entame, puis initialisation de la production par la préparation d'une crête à un versant préparé.

Phase n°2 : détachement de la lame à crête, puis débitage des premiers supports laminaires, partiellement corticaux, de courbure variable, et de fort gabarit. Ces produits sont principalement transformés en grattoirs sur lame ou en lames à retouches continues sur un bord.

Phase n°3 : entretien du plan de frappe par le détachement d'une tablette de réfection totale, et de la convexité longitudinale de la table, par la mise en jeu d'un plan de frappe opposé à partir duquel sont uniquement produits de petits éclats courts. Puis poursuite de la production par le débitage de petits supports de "plein débitage" et de profil rectiligne . Ces derniers sont essentiellement destinés à être transformés en pièces à dos, et principalement en pointes de Châtelperron.

Schéma récapitulatif de la production laminaire sur éclat

Phase n°1 : initialisation de la production, transversalement en partie distale du support, par le détachement d'une crête à un versant préparé depuis la face d'éclatement de l'éclat vers sa face supérieure.

Phase n°2 : production des premiers supports laminaires à pan revers, puis entretien de la convexité transversale de la surface de débitage par la mise en place d'une lame néo-crête.

Phase n°3 : poursuite du débitage de petites lames de profil rectiligne , mais sans pan revers. l'ensemble des supports produits semblent principalement transformés en pièces à dos diverses (lames à bord abattu, troncatures obliques et pointes de Châtelperron)

Figure 8. Chatelperronian reduction sequence from Bachellerie (2011, 305-6 fig. 159-60).

Bordes (1973, 218) noted that it was Peyrony who distinguished the Aurignacian and the Perigordian (Chatelperronian and Gravettian), which until that time had been classified under a generalized Aurignacian typology. Prior to this point, Abbé Breuil's system maintained that all Upper Palaeolithic traditions prior to the Solutrean belonged to the Aurignacian in which consisted a tripartite division (Table **2**). Under Breuil's schema, what is now typed as the Chatelperronian was defined as the *Lower Aurignacian*, the Aurignacian *sensu stricto* was called the *Middle Aurignacian*, and the Gravettian was considered the *Upper Aurignacian* (Harrold 1981, 2).

Cultural Systematics

Current	Peyrony	Breuil
Gravettian V	Perigordian V	Upper Aurignacian
Gravettian IV	Perigordian IV	
Aurignacian IV	Aurignacian IV	Middle Aurignacian
Aurignacian III	Perigordian III	
Aurignacian II	Aurignacian II	
Aurignacian I	Aurignacian I	
Protoaurignacian	Perigordian II	Lower Aurignacian
Chatelperronian	Perigordian I	

Table 2. Early to Middle Upper Palaeolithic systematics reformatted from Blades 2001, 44 table 2.2.

Though no longer largely accepted (Lévêque 1997, 280), the Perigordian tradition even if not a true cultural-historical phenomenon does seem to share a similarity in type fossils, largely unilaterally backed blade elements and burins on blades that ultimately distinguish the Chatelperronian and Gravettian from the Aurignacian. The Chatelperronian is thus characterized as possessing "apical lithic points" and this descriptive is equally applicable to the Gravettian (*see* Figure **9**) whereas the Aurignacian possessed "weapons armed with antler or wood points, only some of which had bladelets attached" (Bachellerie et al. 2011, 152).

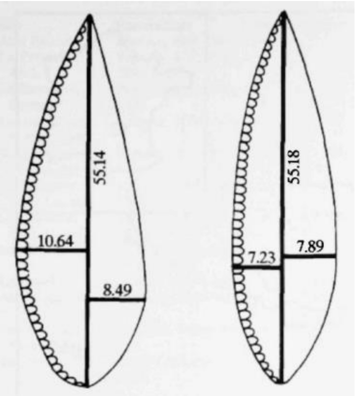


Figure 9. Average metrical traits of Chatelperronian (left) and Gravette (right) points (Harrold 1993, 71 fig. 5.2).

With Sonneville-Bordes' removal of the Protoaurignacian from Peyrony's Perigordian system, the link between the Chatelperronian and later Perigordian industries was called into question (Harrold 1981, 3). To this end, Pradel typed the lithic assemblage from Level G as a Perigordian II, filling the gap left by Sonneville-Bordes' critique. He placed this final expression of the Chatelperronian within Peyrony's Perigordian classificatory system, however, he deviates from Peyrony by classifying the Les Cottés Chatelperronian horizon as the Perigordian II. Under Peyrony, the Perigordian II corresponds to the Protoaurignacian (Blades 2001, 44 table 2.2). Further, Lévêque (1997, 280) notes that Sonneville-Bordes defines the Perigordian II as an early Aurignacian.

The realization that the Perigordian was not a unified cultural trajectory sparked what has become intensive research into the relationship between the Chatelperronian, Aurignacian, and Gravettian as three independent archaeological realities. This was compounded by the findings of a Neanderthal burial within a Chatelperronian context at Saint-Césaire (Lévêque and Vandermeersch 1980), shifting the weight of research toward the relationship of the Chatelperronian and Aurignacian.

The Chatelperronian is considered to have evolved out of the Mousterian of Acheulean Tradition (MTA) B (Pelegrin 1995; Soressi 2005; Pelegrin and Soressi 2007). This is because of the presence of some Mousterian-type tools in Chatelperronian assemblages and the morphological similarity between the MTA backed knives to Chatelperronian points (knives). The relationship between the two industries was first raised by Sonneville-Bordes (Zilhão et al. 2008, 2). Bordes also hypothesized a cultural and morphological evolution from late Perigordian Neanderthals to AMHs with a Chatelperronian culture (Harrold 2000, 64). Recent studies have questioned the relationship between the MTA and Chatelperronian on chronological grounds (Bordes and Teyssandier 2011; 2012). Even if the direct relationship between the MTA-B and the Chatelperronian is less certain than previously assumed, the late Middle Palaeolithic record demonstrates that many of the technological aspects seen in the Chatelperronian were not unprecedented.

For example, the final Mousterian at Audi rock shelter presents backed knives akin to the Chatelperronian type-fossil (Pradel 1952; 1966 *see* Figure **10**), and the Chatelperronian is found in superposition over the late Mousterian at La "Ferrassie, Germolles, La Roche-au-Loup, Haurets, [and] Gargas" (1952, 537). Likewise, the Chatelperronian is characterized as containing Mousterian types such as small bifaces, Mousterian points and side scrapers (Pradel ibid, 537).

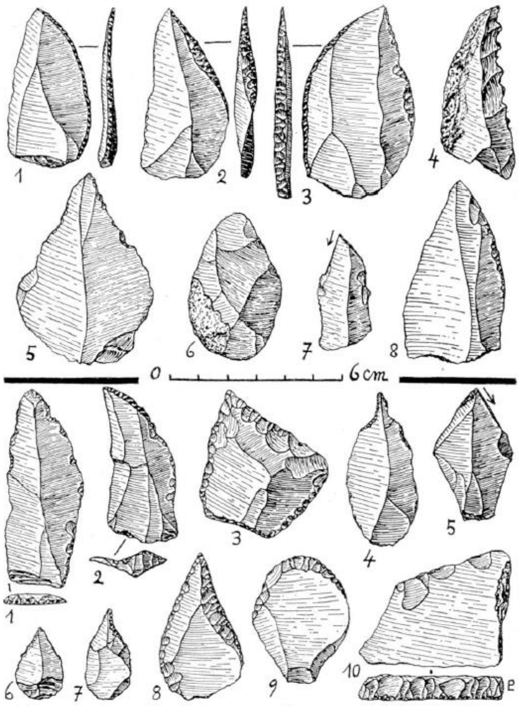


Figure 10. Final Mousterian elements from Audi rock-shelter and Fontmaure (Pradel 1966, 34 fig. 1).

Recent research has further demonstrated technological similarity between the Mousterian and Chatelperronian with the discovery of bone lissoirs within the MTA-B horizons of Pech-de-l'Azé I and Abri Peyrony (Soressi et al. 2013). In fact, the occurrence of the MTA-A and MTA-B within late to middle MIS3 strengthens the argument that the late Mousterian represents shifts toward Upper Palaeolithic-type adaptations and that these were autochthonous Neanderthal inventions rather than influences from AMH from further afield (*contra* Mellars 1999).

Current research then seems to uphold the assumption that the Chatelperronian is indicative of a late Neanderthal presence in Europe prior to the arrival of modern humans. The association of Neanderthal skeletal remains in stratigraphic association with the Chatelperronian at Saint-Césaire (Lévêque and Vandermeersch 1980) as well as Grotte-du-Renne (Bailey and Hublin 2006) leaves little room for doubt in this regard.

-Aurignacian

The Aurignacian is typically seen as representing the first widespread occurrence of modern humans across Europe and the Near East (Mellars 2004a). The industry is characterized by carinated and nosed scrapers, end scrapers on marginally retouched blades, marginally retouched strangulated and Aurignacian blades, Busked and Vachon-type burins, Dufour and Font-Yves retouched bladelets, split-based bone, lozangic and biconical ivory and antler points (Figure **11**) as well as non-utilitarian items, ornaments and extensive pigment use (Davies 2001, 198).

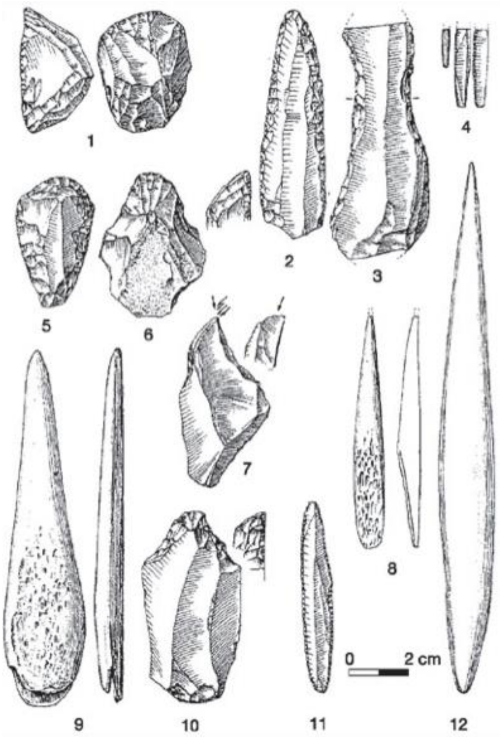


Figure 11. Typical elements of the Aurignacian (Mellars 2004a, fig. 4).

The industry is divided into at least three general phases, the Protoaurignacian, the Early Aurignacian and the Evolved Aurignacian (after 32kRCY), which can be differentiated on the grounds of tool typology, lithic reduction, and cultural material (Teyssandier et al. 2010).

The carinated end scraper, for example, is a diagnostic type-fossil of the Early Aurignacian. This type is now understood to be a bladelet core (Teyssandier et al. 2002, 246) for the creation of small semi-twisted bladelet blanks that were utilized either unmodified or were retouched into Dufour bladelets inset into bone or wooden armatures (Bachellerie et al. 2011, 152). Djindjian (2012, 76-77) notes that blade and bladelet technology for which the Aurignacian is best described is well adapted to a highly mobile strategy with the reduction of cores occurring at raw material outcrops, and cores being transported back to the caves or rockshelters to be cached or curated for the production of blanks *on the go*. Though there was a high objective emphasis on bladelet production within the Protoaurignacian (Figure **12**), carinated cores were not a common feature of this technocomplex (Banks et al. 2013a), which is important to note, as this industry comprises the first phase of the Aurignacian chronology.

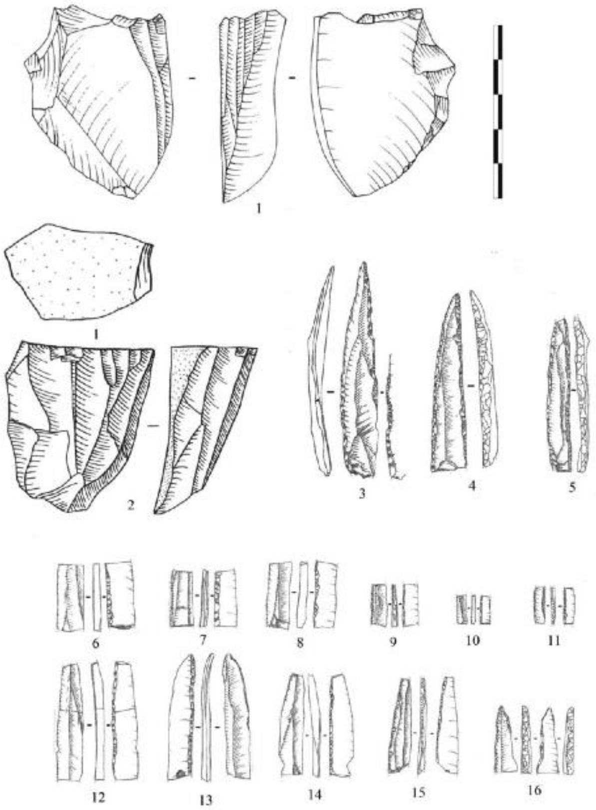


Figure 12. Typical elements of the Protoaurignacian from Bachellerie (2011, 395, fig. 187).

Interestingly, carinated end scrapers (cores) are not unprecedented during the Middle Palaeolithic in areas where the Mousterian transitions into the Aurignacian. In fact, both in the Rhone Valley and along the German side of the Rhine, carinated scrapers first appear during MIS4. For example, the Quina Mousterian assemblage from Le Figuier in the Rhone Valley (Moncel and Daujeard 2012) contains carinated elements (Figure **13**).

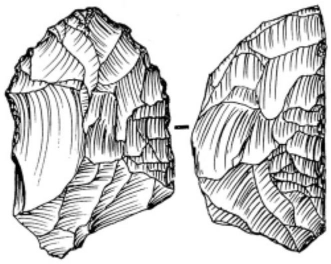


Figure 13. Carinated piece from Le Figuier (Moncel and Daujeard 2012, 115 fig. 16).

Further, the Middle Palaeolithic assemblage from Volkringhauser Höhle, also demonstrates the utilization of bladelet technology within the Middle Palaeolithic. The reduction system is still Middle Palaeolithic in nature, the main blank type being flakes (n = 72), but the next largest blank category is bladelets (n = 21) (Tafelmaier 2011, 157 table 6). Bladelet production is almost exclusively on non-local flint (n= 20). Further, these bladelets were produced utilizing a hard hammer method with a diverse range of reduction strategies including carinated cores (ibid, 165).

However, the Volkringhauser assemblage lacks a clear stratigraphic context, which should caution the strength of any behavioural interpretation derived from this dataset. This is not the case with the nearby site of Balver Höhler (Tafelmaier 2011, 175), which seems to confirm the place of carinated cores and bladelets as intentional products of a glacial adaptation within Middle Palaeolithic/Micoquian repertoire, lending credence to the observations at Volkringhauser. To this end, it could be argued that the carinated core type is a product of more generalized unidirectional and opportunistic bladelet production techniques, as this core type is present throughout all five Middle Palaeolithic horizons at Balver Höhle (Pastoors and Tafelmaier 2010). Similarly, the more general use of bladelets during the Middle Palaeolithic was a widespread phenomenon (Figure **14**).

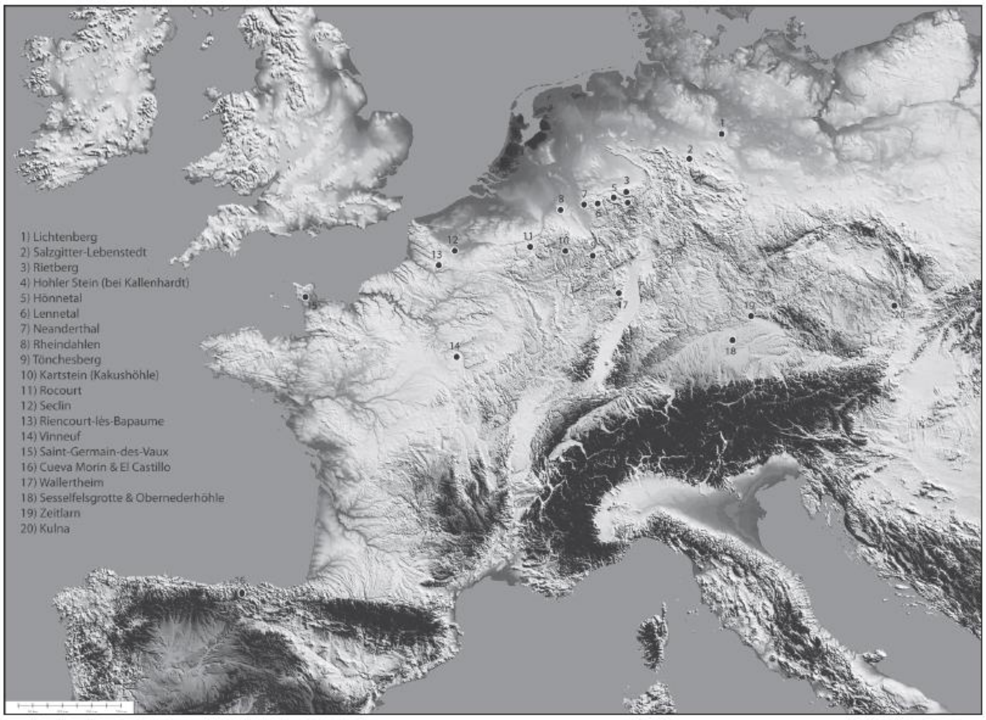


Figure 14. Middle Palaeolithic sites with blades and bladelets (Tafelmaier 2011, 168 fig. 16).

The utilization of bladelets in the Middle Palaeolithic of the Rhine makes their near absence in the Jura Aurignacian puzzling. Hahn formulated a system for the Aurignacian of Swabia typed on Geissenklösterle demonstrating a uniquely Aurignacian reduction process that has been upheld by Teyssandier and Liolios (2003). The site's assemblages only contain two bladelets, 1 Dufour and 1 Font-Yves, out of the entire Aurignacian sequence with the earliest Upper Palaeolithic level lacking both key Protoaurignacian type-fossils (i.e. Font-Yves bladelets) and Aurignacian types (i.e. osseous points) (ibid, 182). The deepest Upper Palaeolithic levels in the Jura seem most closely related to the Early Aurignacian rather than the Protoaurignacian with the presence of carinated end scrapers, thick blades, and strangulated blades (Teyssandier 2006). The Aurignacian assemblages from Geissenklösterle and Hohle Fels as well as the surrounding region, are sometimes referred to as the 'Swabian Aurignacian' due to the above noted uniqueness of these assemblages (Figure **15**).

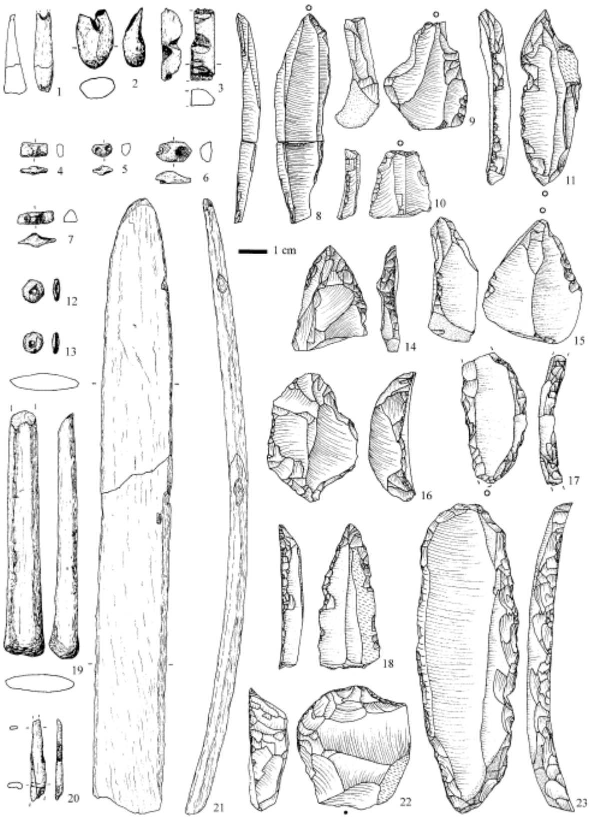


Figure 15. Elements of the Swabian Aurignacian from Hohle Fels (Conard and Bolus 2003, 348 fig. 8).

This issue highlights the fact that the exact characteristics and position, indeed the definition of the Aurignacian itself, has changed over the past hundred or more years. Originally, the Upper Palaeolithic sequence prior to the Solutrean was consigned to a generalized *Aurignacian* (Bordes 1973), as previously noted. Bordes (ibid) states that this definition was a manifest result of cultural evolutionary biases under which the European Upper Palaeolithic system was applied on a global scale. It was Peyrony who subdivided the Aurignacian into the Perigordian and Aurignacian technocomplexes with each representing their own parallel evolutionary subdivision (ibid).

This was still not the Aurignacian as currently defined, as the Protoaurignacian was tentatively assigned to the Perigordian under this cultural system (Table **3**). However, Pradel (1953) noted in his examination of the *Perigordian* that the archaeological levels largely characterized by three tool types, Font-Yves points, Dufour bladelets, and carinated scrapers form a distinctly separate cultural expression from the Chatelperronian and Gravettian. Nonetheless, he also notes that the Font-Yves point as a fossil type is problematic as its use continues late into the Upper Palaeolithic (ibid, 542).

Peyrony's Schematic for the EUP levels of La Ferrassie

Level	Cultural Classification	Type-fossils	Modern Classification
H (III)	Aurignacian IV	Biconical points	Aurignacian IV
G (III)		Sterile	
H (II)	Aurignacian III	Oval-section points	Aurignacian III
G (II)		Sterile	
H	Aurignacian II	Lozengic points	Aurignacian II
G		Sterile	
F	Aurignacian I	Split-based point	Early Aurignacian
E (II)	Perigordian II	Font-Yves point	Protoaurignacian
E	Perigordian I	Chatelperronian knife	Chatelperronian

Table 3. Peyrony’s early Upper Palaeolithic schematic for La Ferrassie compiled from Blades 2001, 37-38.

The same might also be said of the certainty of the demic association of Aurignacian, as there have been some issues with the stratigraphic security of AMH remains with this industry (Conard et al. 2004). Nonetheless, it is commonly held that the Aurignacian was an AMH product (Mellars 2006a). Likewise, it is assumed in this thesis that the Aurignacian *sensu lato* is a marker of modern humans for the same reasoning that it is assumed that the Chatelperronian was a Neanderthal product, the stratigraphic association of skeletal remains with the technocomplex. This appears to be the case at Oase and Mladec, the oldest reliably diagnostic modern human remains in Europe (Smith et al. 2005), and AMH dental, primarily deciduous, specimens have been associated with a number of Aurignacian contexts (Bailey et al. 2009).

Thesis structure and chapter summations

The thesis is divided into multiple chapters dedicated to the development of the research model, the discussion of relevant theoretical arguments, and the implementation/testing of the model itself.

Band model outline (Chapter 2):

In this chapter, I outline the band model. This involves a discussion of how Layton and O'Hara define hunter-gatherer societies as multilevel systems composed of family units, bands, and larger communities (*regional groups*). At the end of the chapter, I put forward the hypothesis: Neanderthal and AMH fission-fusion behaviours were not comparable. I then outline three supporting test propositions to be examined in the thesis.

Fission-fusion part 1 (chapter 3):

This is the first of two chapters in which I discuss the field of fission-fusion studies. In this chapter, I outline the fission-fusion behaviour of three non-primate species and three primate species. I then move on to discuss commonalities in the social behaviours of these species and highlight some potential concerns about formulating a cross-species model of fission-fusion behaviour.

Fission-fusion part II (chapter 4):

In this chapter, I focus on human fission-fusion behaviour. I give specific cultural examples to examine how fission-fusion mechanisms are employed to manage social alliance, conflict mitigation, and ecological adaptation. Careful attention is given to how a fission-fusion social organization enables hunter-gatherer communities to adapt to specific environmental and ecological conditions.

Theoretical background part I (Chapter 5):

This chapter provides a discussion of existing theories and models concerning the evolution of human social complexity during the Pleistocene. I then move on to discuss how the band model relates to these existing ideas, arguing that the band model is unique because it frames the elaboration of human social complexity with a deeply rooted primate, fission-fusion behaviour.

Theoretical background part II (Chapter 6):

In this chapter, I focus on arguments over lithic technology during the late Pleistocene and how they relate to the understanding of social organization and territoriality. I outline the method employed to examine lithic raw material source-to-site distances as a proxy for past territorial areas. This allows a discussion of Neanderthal and AMH territoriality as inferred from patterns in lithic material sourcing during the Middle and Upper Palaeolithic.

Methods (chapter 7):

In this chapter I discuss the methods I use in this thesis to test the three supporting propositions that hold up the hypothesis that Neanderthal and AMH fission-fusion behaviour was not comparable. I put forth two syntheses that provide a cultural and environmental reference point and an outline of the socioecology of the main species that compose the faunal assemblages examined in the thesis. I then outline the methods employed to develop a heuristic and statistical examination of fission-fusion adaptation. I conclude by outlining two macro-level models of long distance material sourcing and demography during MIS4 to MIS2.

Testing the hypothesis part I (Chapter 8):

I examine estimates for Neanderthal and AMH group sizes in this thesis. Using a sample population of cranial volumes of *H. heidelbergensis*, a test whether a modern brain size was a convergent or ancestral trait shared by Neanderthals and AMHs. I move on to examine the encephalization index of both demes and the potential that Neanderthal cognition was subject to different selective pressures than that of AMHs.

Les Cottés (chapter 9):

In this chapter, I discuss the transitional site of Les Cottés. I provide a discussion of the regional setting of the site and research history. A summary of the site stratigraphy, archaeological sequence, faunal assemblages, chronology, and environmental setting is given. I conclude the chapter with a discussion of the relationships between the pattern of lithic sourcing and environmental signature recorded at the site.

Comparative study area (chapter 10):

This chapter provides a summary of the Palaeolithic sequences from Geissenklösterle and Hohle Fels. I follow a similar format to that for Les Cottés. Likewise, I end the chapter with a discussion of the relationship between the lithic sourcing pattern and environmental pattern recorded at both sites.

Testing the hypothesis part II (chapter 11):

In this chapter, I apply the heuristic and statistical analyses outlined in the methods chapter to examine Neanderthal and AMHs fission-fusion behaviour. I expand the dataset to include two Quina Mousterian levels from Les Pradelles in order to even out the sample to include a similar sized Middle Palaeolithic sample to that of the Upper Palaeolithic. I concluded the chapter with a model of long distance lithic sourcing and demography from 75KYA to 12KYA.

Discussion (chapter 12):

This chapter provides a discussion of the test results. I examine potential implication of the results and move on to discuss the relationship between long distance and local sourcing patterns during the late Pleistocene. This chapter also provides a discussion of the predictive power of both the long distance lithic sourcing model and demographic model.

Conclusion (chapter 13):

In this chapter, I provide a summary of the test results and chapters. I move on to offer further thoughts and research avenues that stem from the application of the band model in this thesis.

Research outcomes

As noted, there are three primary research objectives: the testing for the emergence of a modern level of encephalization as a proxy for group size and changes in dietary/subsistence regimes, the examination of the archaeological dataset for relationships between lithic sourcing and environmental patterns, and a macro-level analysis of long distance lithic material sourcing and demography from the Middle Palaeolithic to later Upper Palaeolithic. These research objectives have been designed to test the applicability and analytical power of the fission-fusion based band model.

Testing for the emergence of a modern level of encephalization:

I test for the emergence of a modern rate of encephalization within the hominin lineage by comparing modern human, Neanderthal, early AMH, *H. heidelbergensis*, and *H. erectus* sample populations. From the results of this analysis, I conclude a modern rate of encephalization evolved prior to the divergence of the Neanderthal and AMH lineages ~270kya (Green et al. 2010). I, therefore, conclude that there is no reason to assume that Neanderthals or modern humans would have deviated from Dunbar's (Dunbar 1992; Dunbar and Shultz 2007) well-established relationship between brain size and group size within Simiiformes (Figure **16**). This is taken to imply that group demography and dietary requirements of Neanderthals and modern humans would have produced similar selective pressures on the fission-fusion dynamic of both demes.

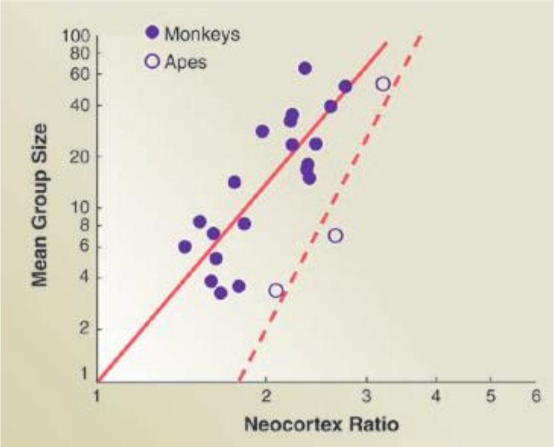


Figure 16. Relationship between brain size (neocortex ratio) and mean group size within Simiiformes (Dunbar and Shultz 2007, 1344 fig. 1).

Testing the archaeological dataset:

Within this analysis, I examine the environmental contexts, chrono-stratigraphy, and lithic material sourcing of Les Cottés, Geissenklösterle, and Hohle Fels. I expand this analysis to include two Quina Mousterian levels from the site of Les Pradelles. Patterns in lithic raw material are shown to trend very well with environmental and ecological conditions regardless of demic association. Local lithic material sourcing, at all four sites with levels spanning the Quina Mousterian to the Magdalenian, correlates with a very high degree of confidence with faunal patterns. I interpret this as suggesting that environmental carrying capacity and resource patterning shaped both Neanderthal and Upper Palaeolithic AMH fission-fusion patterns in a similar way to that of modern hunter-gatherers.

Macro-level model and analysis:

Starting from the above survey area observations, I expand my examination to include macro-level environmental data and trends in lithic material transport from the end of MIS4 to the onset of the Holocene. I extrapolate these observations to a macro-level environmental dataset, seasonal temperature estimates from the long sequence at La Grande Pile, generously provided by Joel Guiot. From this data, I produce a predictive model that provides estimates for long distance lithic material sourcing and demography from MIS4 to MIS2. This model assumes that the fission-fusion behaviour of Neanderthals and modern humans functioned comparably. I conclude from this model that environmental processes rather than sociobehavioural differences between

Neanderthals and modern humans best account for changes in network/interaction areas from the Middle to Upper Palaeolithic.

-General research outcomes

1. Neanderthal and AMH group sizes should have been the same according to the assumption of the *social brain hypothesis*.

2. Neanderthal and AMH territorial areas and population densities are estimated to have fallen within the range known for modern hunter-gatherers.

3. Environmental forcing most likely describes regional and chronological differences in material sourcing patterns throughout the Middle and Upper Palaeolithic.

4. Difference in Neanderthal and AMH demography was most likely the result of environmental pressure rather than a difference in the sociality of either deme.

5. Band communities would have suffered a dramatic demographic collapse during the time range of the Middle to Upper Palaeolithic transition due to environmental and ecological deterioration.

6. There were differences in the fission-fusion patterns between the late Middle Palaeolithic and Upper Palaeolithic as gross units, but this was the result of a common adaptive mechanism to different ecological conditions and not genetically underwritten, behavioural differences.

Conclusion

In this chapter, I have introduced the thesis by providing background information pertinent to the test model, outlined the research objectives and subsequent chapters, and provided a summation of the research outcomes. The central aim of this thesis, as stated, is to adapt Layton and O'Hara's band model (2010) to archaeological investigation. Grounding the analysis of behavioural modernity in a fission-fusion studies approach has produced interesting and compelling results. The following chapter outlines the band model and highlights aspects of this model that are particularly suitable for the creation of archaeologically testable hypotheses.

CHAPTER 2

Band model outline

Introduction

As discussed in the previous chapter, recent archaeological and paleogenetic evidence problematizes existing behavioural modernity models. Most significant of these is the realisation that Neanderthals and Denisovans contributed directly to the genetic makeup of extant human populations (Green et al. 2010; Meyer et al. 2012). Models that assume a singular origin point for behaviourally and morphologically modern humans cannot encompass the complexity of the current genetic and archaeological records. This makes it difficult to generate meaningful and falsifiable propositions regarding the evolution of human social complexity. A model of human social behaviour at a hunter-gatherer level of subsistence and organization may better contextualize the current empirical dataset into a meaningful narrative. The *band model* proposed by Layton and O'Hara in 2010, which has been further developed by Layton et al. (2012) provides such a model.

Situated within the broader field of fission-fusion studies, the band model looks at the multi-level structure of hunter-gatherer societies, thereby elucidating shared patterns of social behaviour between these communities. The *band model* along with research into fission-fusion behaviour has generated interest within recent anthropological investigations into the evolution of modern social behaviour (Gowlett et al. 2012; Grove et al. 2012; Layton et al. 2012; Dunbar et al. 2014; Pearce et al. 2014). This chapter provides a synopsis of the band model and synthesizes elements of this model most pertinent to archaeological investigation. From this synthesis, test propositions are drawn, which will form the basis of further investigation in this thesis.

Forging a way forward: the band sociality model

Hunter-gatherer societies can be divided into two primary levels beyond the familial unit: the band and the regional group. Chimpanzee societies are divided into troops and foraging parties. Examining hunter-gatherer multilevel sociality within a fission-fusion studies framework, Layton and O'Hara (2010) argued that the human band should not be compared to the chimpanzee troop (the maximal community for both species of *Pan*). Rather, human bands should be understood as being similar to chimpanzee foraging parties. They argue that the maximal band or *regional group* of hunter-gatherers, often unified by a single dialectical commonality, should be associated in comparative studies to the chimpanzee troop. This is an important distinction, as by arguing this point, Layton and O'Hara diverge from the longstanding assumption that regional groups are held together by inter-band alliance. Instead, they see the band as a more lasting fission moment within the function of a greater community. This community is then maintained by a common dialect and the formulation of alliances based on kinship and moieties that crosscut the boundaries of individual bands.

Examining multiple hunter-gatherer groups from savanna, semi-desert, temperate coast, boreal forest, and arctic environments, Layton and O'Hara note that bands on average number ~25 individuals and that the larger *regional g*roup is composed of ~500 individuals (Figure **17**). Like Marlowe (2005), they note that both the band and regional group community levels are not greatly affected by ecological pressure, but rather population density is underwritten by ecological circumstance. Therefore, the number of agents that comprise hunter-gatherer communities is fairly constant regardless of environmental circumstance, but that territorial size and population density is highly variable between hunter-gatherers living in different ecological zones.

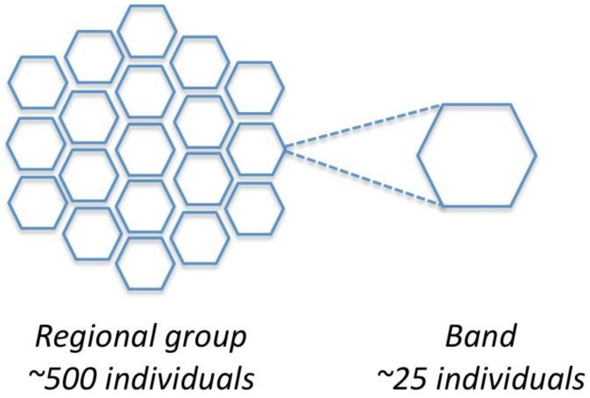


Figure 17. Diagram of hunter-gatherer multilevel social organization, *band* sociality system.

Layton and O'Hara (2010) and Layton et al. (2012) contend that it is the interlacing of individual membership across these levels of band society that the community is formulated and band membership is negotiated. The networking of alliances cannot be reducible to individual concerns, as members of individual bands are actively encouraged to seek spouses beyond the band level. Williams observed that in Birhor communities, marriage arrangements are formulated by parents and their co-residents (2009, 155). This, Layton and O'Hara (2010) argue in much the same way as Whallon (2006), acts as a delayed return investment by the band to mitigate potential resource pitfalls within their territorial stewardship through gaining access to other bands' territory with which they have established socially regulated connections.

Aggregation/Dispersion and Multilevel Organization:

Layton et al. (2012), examining multiple ethnographic accounts, note that hunter-gatherer communities present three levels of social organization: the *regional group* or maximal 'community,' the 'band,' and the 'domestic unit.' These organizational levels are products of a uniquely human fission-fusion dynamic that they argue is deeply rooted within the human clade.

The Community i.e. *Regional Group*:

The *regional group* is comprised of a network of bands that are "frequently characterized by a distinct dialect or language" (Layton et al. 2012, 1221). Within a hunter-gatherer community, agents are relatively free to move between bands, and there are less social obstacles to forming interpersonal alliance within the 'community' than beyond it. To this end, Layton et al. cite several instances of hunter-gatherer communities unifying to defend group territory and resources from external incursion. Marriages further strengthen the interdependency of bands, and are almost exclusively formulated within the confines of the *regional group*. They note that the average size of hunter-gatherer communities, at "250-500" agents, conforms well to Wobst's (1974) prediction for functional endogamy, enabling the *regional group* to act as a "breeding isolate" (Layton et al. 2012, 1221). Important to archaeological interpretation, Layton et al. observe that the degree, scale, and timing of larger aggregations in hunter-gatherer communities are highly variable. The resource strain that large-scale aggregations cause mean that such events only occur "where resources are exceptionally dense" (ibid, 1222). In some environments, aggregation is limited to a maximum of 150-200 individuals and again only when resources are most abundant.

The Band:

The band level of hunter-gatherer society is the largest social unit in which agents will interact with one another throughout the majority of their lifetime. Band membership is quite flexible with the disassociation of bands being preferred to inter-agent conflict.

Agreeing with Marlowe's (2005) finding that the number of members in a human band is independent of ecological constraint, Layton et al. note that the number of agents that comprise a band in their ethnographic sample of "27 hunter-gatherer peoples" averages between 25-35 individuals (2012, 1226). However, there are specific differences between some groups, which appear to be associated with hunting highly gregarious and migratory species, resulting in seasonally dependent large band aggregations.

The number of bands within any given *regional group* can range between 5 and 61, with an average of ~18 bands (Layton et al. 2012, 1226). As noted above, band membership is often flexible, and this flexibility may mechanistically "equaliz[e] band size" (ibid, 1227). Open band membership allows for the diffusion of inter-agent conflict as well as a means to mediate the ecological stress of population loading on any given band territory without damaging the stability of the hunter-gatherer community or the ability for the community to act as a largely independent entity. It is for this reason that Layton et al. argue that the *regional group* is comparable to the chimpanzee troop. They argue that bands are an emergent property of the *regional group* (*contra* Marlowe 2005 who assumes that the emergence of language enabled humans to formulate larger communities through inter-band alliance). This is important when the fact that hunter-gatherer communities can form a closed breeding network is taken into consideration. Chimpanzees on the other hand have an exogamous mating system. This shift from community exogamy to community endogamy may suggest that the large size of human communities evolved to guarantee fecundity despite very low population densities.

The Family Unit:

The hunter-gatherer 'domestic unit' appears in many ways unique to human sociality compared to other members of the Hominidae. This is because familial units are composed of a socially regulated pair-bonded dyad. However, there is a significant degree of variation within hunter-gatherers as to how nuclear kinship is expressed. Though hunter-gatherers may tend toward monogamous dyads, polygamy is common among some groups with "the majority of unions in some north Australian societies" being polygynous (Layton et al. 2012, 1224). Layton et al. argue that pair-bonding must have evolved with the human band, as bonded dyads or polygynous units rely on the "mutual aid" of the band (ibid, 1225). The main reason for this recursive benefit of bonded-pairing and band membership stems from the gender division of labour among hunter-gatherers. This division of labour means that male and female subsistence strategies are differentiated and the cooperative activities must take place beyond the confines of the bonded dyad. The band allows the cooperative activities of male and female segregated labour to be effectively accomplished. The centralized pooling and sharing of resources at the end of the day at base camps insures the mutual benefit of each dyad and as well as dependent agents, such as children and the elderly.

From an evolutionary standpoint, the emergence of socially mediated mating dyads would have resulted in a reduction in male-male mating competition, and more importantly, the possibility of "bilateral kinship" (Layton et al. 2012, 1225). To this end, Layton et al. argue that "reciprocal gift-giving [and] alliance through marriage" are uniquely human social behaviours (ibid). As further elaborated by Layton and O'Hara (2010), bilateral kinship enables the movement of bonded-pairs between bands, enabling nuclear families to spread the cost of dependent offspring between more than one band. Often the movement of nuclear families is dependent upon the ontogeny of offspring with uxorilocal cohabitation most common during the first year(s) of a neonate.

Release from Proximity VS Exile from Proximity:

Layton et al. argue against the assumption that "humans experienc[ed] a 'release from proximity'" (2012, 1230; *contra* Rodseth et al 1991). Instead, shifts in the human diet along with increased hunting based subsistence "enforced an exile from proximity" (ibid). This is because the evolution of a diet based on the exploitation of high-tiered resources limited the number of caloric resources available to human communities. The idea of linking hominin carnivory with what Layton et al. denote as exile from proximity can be traced back to Washburn (2009). Washburn observed that many primate species live at a population density near if not in excess of that seen only in agricultural societies. This led him to question the then held belief that shifts toward higher rates of carnivory would have been beneficial to hominin population numbers.

There is a causal distinction between *release from proximity* and *exile from proximity* that is very important (Figure **18**). The release from proximity paradigm implies that selection on hominin social intelligence enabled interpersonal relationships to be removed from the immediate, face-to-face, realm that primate social cohesion can be largely described. With the capacity for language and symbolically mediated culture, inter-agent bonds and inter-band alliances could be formulated "in absentia" (Gamble and Gittins 2004, 102). Through the use of ritualistic behaviour, group aggregations create social liminality where individuals are united, reinforcing social bonds and ameliorating stress caused by social absence (Rodseth et al. 1991).

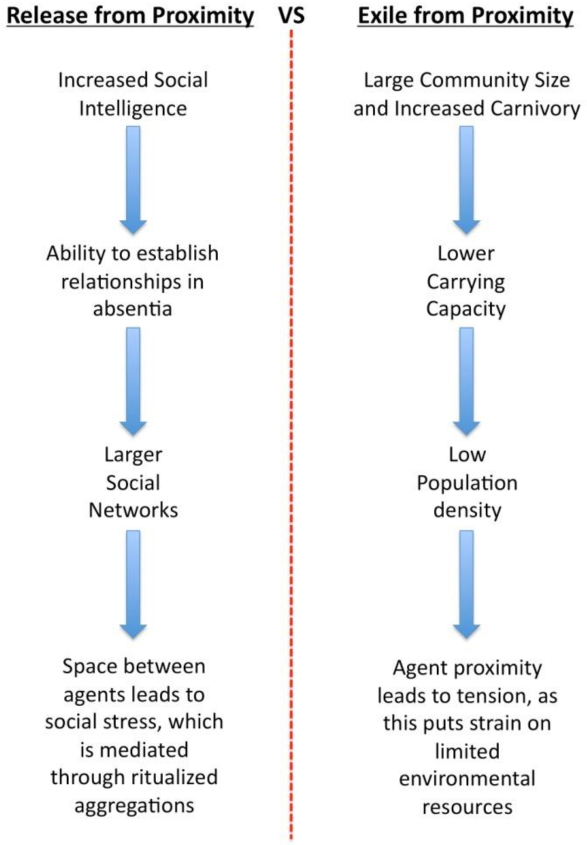


Figure 18. Outline of the 'release from proximity' and 'exile from proximity' arguments.

Layton and O'Hara (2010) note that community aggregations can lead to the reformulation of social alliances and the arrangement of marriages. However, aggregations have a functionalistic or mechanistic role of alleviating inter-personal conflicts that form between band members. Turnbull (2009) for example argues that close cooperative organization among his Mbuti informants led to high levels of inter-agent stress and antagonism, leading even to false accusations of wrong doing. Instead, it was at the time of fissioning that internal social stress becomes ameliorated by proximal separation. Even the communal "great religious songs," of the Mbuti, according to Turnbull, are not directed toward establishing *communitas per se*, but toward the "benevolence of the forest" that enables their release from proximity (ibid, 156).

Exile from proximity assumes that larger hominin communities, in regards to the total number of agents, existed prior to the formulation of the band system seen among extant hunter-gatherers. Shifts in hominin dietary patterns toward higher rates of carnivory, which could be explained within a process of niche specialization, produced the low population densities seen among hunter-gatherer communities. Exile from proximity also assumes that periods of absence pose less of an obstacle to inter-agent relationships than the release from proximity paradigm assumes. Rather, it is during moments of aggregation that the highest level of social stress can occur due to the environmental cost of large numbers of human agents gathered in one place.

Summation of the band model

Layton and O'Hara (2010) suggest that the high level of carnivory, or meat derived calories, in the hunter-gatherer diet has had the greatest affect on population densities. This makes hunter-gatherers subject to the same kinds of low carrying capacities as carnivores. John E. Pfeiffer (1973) made the similar observation that hunter-gather band and wolf pack territory ranges are comparable whereas other living social primates such as gorillas and baboons have territories that are at least thirty-three times smaller. King (1975) also recognized that Palaeolithic communities would have been subject to similar ecological constraints as those of extant social carnivores. It also makes hunter-gatherer demography and territorial parameters highly sensitive to ecological conditions (Figure **19**).

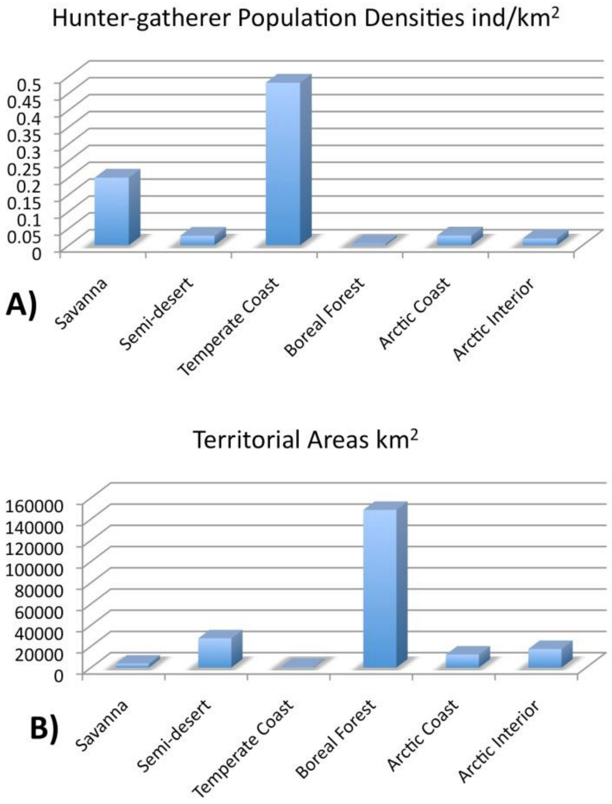


Figure 19. Hunter-gatherer populations densities and territorial sizes. A) Hunter-gatherer population density by ecological zone. B) Hunter-gatherer territorial sizes by ecological zone. Data from Layton and O'Hara (2010, 88-9 table 5.2).

Despite the significant level of difference in population density, the numbers of agents per community are fairly constant between hunter-gatherer groups and largely independent of ecological circumstance.

Since the numbers of individuals that compose hunter-gatherer communities are fairly constant while territorial parameters are dependent on ecological circumstance, there are significant differences in the spatial and temporal distances between bands within the landscape of different regional networks. Changes or differences in the territories of hunter-gatherer landscapes do not reflect differences in the number of agents that compose social networks, but rather the disparity in resource abundance and patterning between environments (Figure **20**). Given that the regional group or maximal community appears preeminent in the course of human evolution, social selection within the human clade would have been placed on the capacity for a flexible fission-fusion dynamic that would enable the spatial and temporal elasticity between units of individuals. The band forms such a unit, enabling hunter-gatherer communities to successfully distribute throughout inhabitable environments.

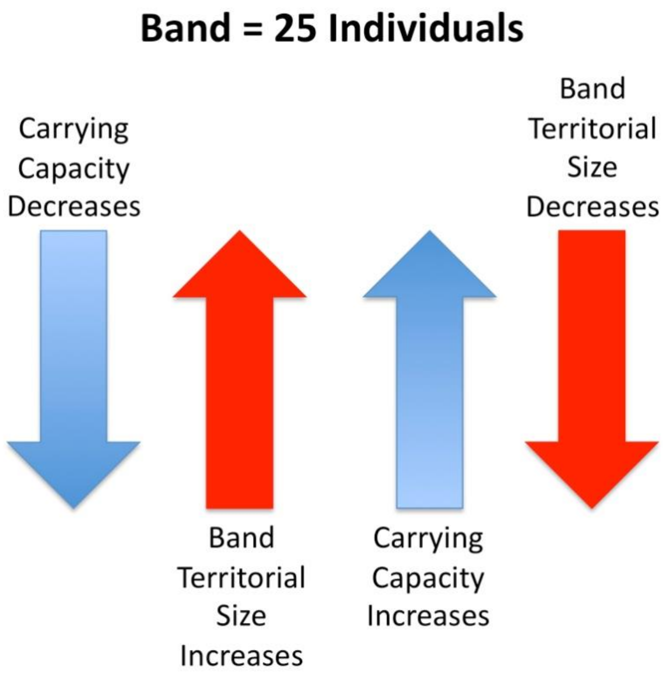


Figure 20. Diagram of relationship between carrying capacity and band territorial size.

Without this capacity, the ecological impact of human communities would be too great on individual patches of land. For this reason, large-scale aggregations are rare among hunter-gatherer communities and entirely dependent on the patterning of resources within given environments. Despite this, contacts between bands are maintained. Contact can be maintained through simple processes such as individuals visiting neighbouring bands to larger *clan* or moiety events that can involve members of two or more bands. The band sociality requires agents that are capable of formulating lifelong ties and a comprehension of the functional benefit of enchainment, as Layton and O'Hara note that the Mbuti describe an individual lacking inter-band alliances as "walking emptily" (2010, 105).

This means that larger groups are pre-existent rather than emergent properties of alliances, therefore the formulation of alliances are directed at the success of familial and band units within the community/regional group rather than to maintain or create the group itself. Therefore, it was not the evolution of alliance systems that were selected for, but the capacity to maintain pre-existing social relationships over greater distances of space and time.

Synthesis

The following synthesis outlines particular aspects of the *band model* that are pertinent to archaeological investigation.

1. Hunter-gather societies are multilevel: bands number ~25 individuals and *regional groups* number ~500 individuals.

2. Regional groups are largely endogamous units.

3. Animal derived calories accounts for 35-41% on average of the hunter-gatherer diet.

4. Increased carnivory in the evolution of the human dietary regime has decreased the number of caloric resources available to human communities.

5. Therefore, the human carrying capacity of an environment is dependent on the frequency and patterning of high-tiered resources.

6. Demography and territorial size are dependent on ecology and so are seasonal fluctuations in the number of members that compose bands.

7. Flexible band membership acts to mediate the impact of populations loading on a given band territory.

8. There is some variability in the seasonal composition of bands of hunter-gatherer communities that hunt highly gregarious and migratory species presenting seasonally dependent large band sizes.

9. Large aggregations are rare and dependent on resource abundance.

10. Differences in environment may increase or suppress large aggregation or fissioning, but intra and inter-band alliances, visits, and exchanges will always be present regardless of environmental circumstances.

11. Alliances between members of different bands within a *regional group* do not bring about the larger community. Rather, bands are dependent on the existence of larger communities or *regional groups*.

12. Alliance through marriage and reciprocal gift giving appear to be unique components of human sociality.

13. The presence of fission-fusion behaviour and cooperative territorial defence in both chimpanzee and human communities suggest that band sociality is deeply rooted in the human clade.

14. Fission-fusion systems enable pongids and humans to maintain larger community sizes than non-fission-fusion species can within similar environments.

15. Like pongids, the interlacing of networks enables humans to have community sizes that are larger than the SBH may predict.

16. Nonetheless, the *social brain hypothesis* can be used to assess group sizes for Neanderthals and AMH (Layton et al. 2012); maintaining community size is a key factor in fission-fusion behaviour.

17. Large community size may have evolved to mitigate the deleterious affect of low population density on exogamous mating systems.

Test propositions

The following suppositions are proposed to examine sociality during the Middle and Upper Palaeolithic within a *band model* framework. The primary object being to examine the long held assumption that the Upper Palaeolithic represents the "arch-types of modern forager societies" while the Middle Palaeolithic represents something other (Bar-Yosef 2002, 363).

-Hypothesis

Neanderthal and AMH fission-fusion behaviours were not comparable.

-Proposition 1

Group size estimates for Neanderthals and AMHs are not comparable, implying that Neanderthal and AMH evolved large brains in parallel and perhaps under different selective pressures.

-Proposition 2

Neanderthal territorial patterns should not suggest population densities that fall within the range of modern hunter-gatherer demography.

-Proposition 3

Neanderthal and AMH territorial parameters did not respond similarly to environmental or ecological pressures.

The analytical steps taken to come to this conclusion are outlined in Figure **21** under the structure of a negative hypothesis.

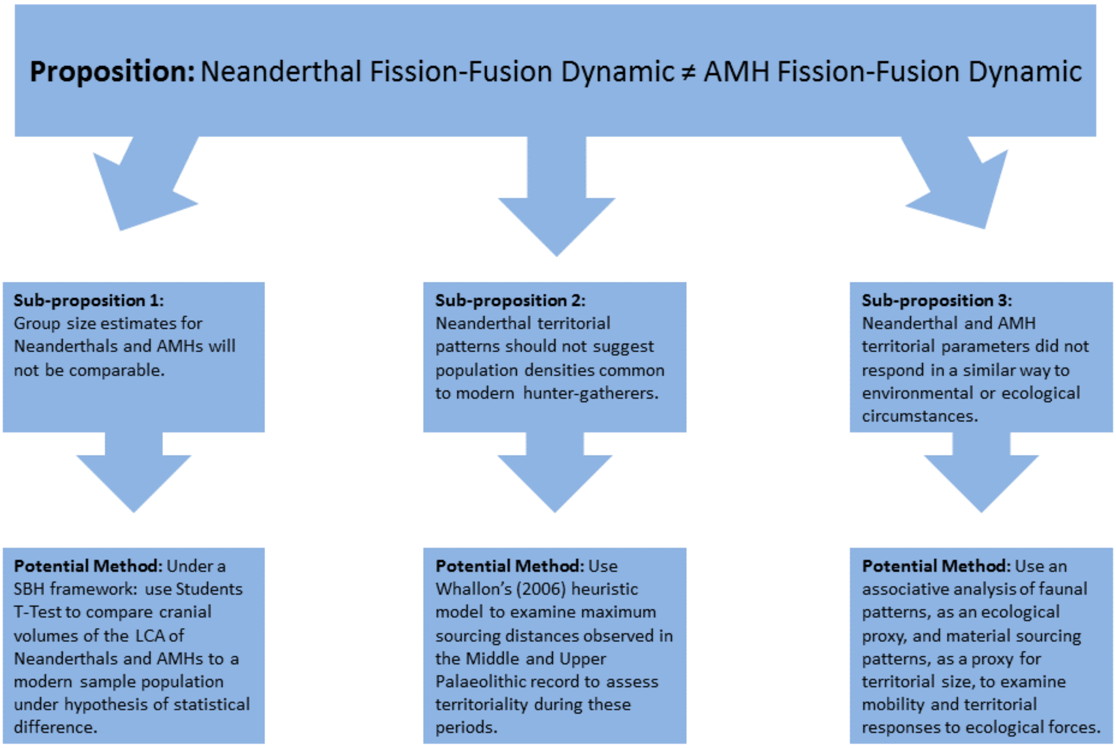


Figure 21. Analytical process of the thesis.

Conclusion

This chapter has provided an outline of the *band model* and has synthesized points of the model that can be useful in formulating archaeologically testable hypotheses. This model is particularly useful as a theoretical framework for modern behaviour. This is because it explicitly details hunter-gatherer subsistence and organizational behaviours into one unified model informed by fission-fusion studies. The following chapters explore fission-fusion studies concerning both non-human and human social behaviour to further situate the theoretical basis of this thesis.

CHAPTER 3

Fission-fusion part I: non-human fission-fusion behaviour

Introduction

In this chapter, the organizational behaviour known as fission-fusion dynamics will be defined and discussed to contextualize the band model within the larger field of fission-fusion studies. This discussion provides a review of fission-fusion behaviour within non-human species. Some common behavioural traits expressed by these species are highlighted. I examine three non-primate cases: elephants, hyenas, and dolphin; and three primate cases: *Pan*, orangutans, and spider monkeys. The review of primate and non-primate fission-fusion behaviour is intended to demonstrate the variability of behaviour within fission-fusion species where specific gender and inter-agent behaviours are concerned while still highlighting some of the ecological factors that contribute to fission-fusion processes at the interspecies level.

What is the field of Fission-Fusion Studies?

Fission-fusion studies is a subfield of behavioural ecology. It is concerned with the social behaviour within communities of some gregarious species, which divide into smaller social units (fission), and then aggregate back into larger units (fusion). In their 'revival' of fission-fusion studies, Aureli et al. (2008) note that the first researcher to apply the term fission-fusion was Hans Kummer (1971) in his work concerning the structure of chimpanzee communities, which he observed divide up into smaller subunits. Though first recognized within the social behaviour of *Pan troglodytes*, several species exhibit this social behaviour, particularly other social carnivores such as hyena and some delphinid (dolphins and orcas) species (Aureli et al 2008, 627-628).

Fission-fusion sociality is often characterized as "a highly flexible system that can respond quickly to environmental changes" (Lehmann and Boesch 2004, 208). This system has "created challenges for social interaction that [have] presented selective pressures for communication and the ability to handle the higher cognitive load associated with larger communities" (Gamble et al. 2011, 121 citing Aureli et al 2008). Van Schaik (1999, 69) notes that there are several factors within non-human species that have an effect on the dynamic of fission-fusion behaviour: "reduced risk of predation; enhanced discovery, exploitation or defence of food; reduced radiative and conductive heat loss; reduced infestation by ectoparasites; and protection against harassment or infanticide." There are of course many factors that contribute to the observed fissioning and fusing of gregarious species.

Nevertheless, one of the primary functions of fission-fusion sociality lies in the capacity of a community to fission into subunits to mitigate environmental constraints that would otherwise be placed on gregarious species. Resource competition is often a primary reason for fissioning. Asensio et al. (2008, 984) note that limited resource availability results in either scramble or contest competition. Scramble competition occurs when non-patched or non-defendable resources become depleted whereas contest competition occurs when a dominant individual denies access to a resource patch. The ability for a community to fission reduces both types of competitive behaviour. Therefore, the community sizes of species that do not have a fission-fusion mechanism are more greatly constrained by carrying capacity. Fission-fusion species, on the other hand, are able to maintain large communities at ecological equilibrium through the fluidity in the cohesiveness of social units. Grove et al. (2012, 196) estimate that if *Pan troglodytes* had not evolved some form of fission-fusion mechanism, then the "maximum ecologically tolerable group size" would be limited "to just 16 individuals, smaller than any known chimpanzee community." The following section provides a brief discussion of some non-human species that possess social systems that have been described as fission-fusion in nature.

Non-Human Fission-Fusion Species

There are several species that exhibit a fission-fusion social structure. This section will focus on only a few of these groups, hyenas: delphinids (dolphin and orca species), elephants, and three types of primates, chimpanzees, orangutans, and spider monkeys. The fission-fusion behaviour of these animal communities shall be reviewed and will be incorporated into a larger discussion of social behaviours shared by this diverse set of species.

Non-Primate Fission-Fusion Species:

Hyenas, delphinids, and elephants may at first glance seem to have very little in common. Two of the selected species are social carnivores, (hyenas and dolphins) while elephants are herbivores. Even though hyenas and delphinids are carnivores, they are adapted to wholly different environmental conditions. Elephants and extant hyenas may share a common ecology, but subsist at either end of the trophic scale. Nonetheless, these species all subsist at comparatively low population densities. As a result, a similar fission-fusion organizational behaviour has independently evolved within the lineages of each of these groups. It is due to the lack of any recent phylogenetic connection between these species that they have been selected for discussion, enabling a synthesis of common behaviours regardless of ancestral structuring.

The low population densities common to these species imply that they must also share relatively large territorial ranges. In a study of Dusky Dolphins, Pearson notes seasonal migrations of individuals over 200km to participate in cooperative hunting, leading in some cases to aggregations of up to 300 agents (Pearson 2009, 1438). This level of seasonal movement and aggregation is impressive and seems to only be equalled by the seasonal and organizational behaviour of some human and cervid communities (Dwyer and Istomin 2008). Likewise, elephants and hyenas both maintain large territorial ranges. According to a study by de Beer and van Aarde (2008, 2021 figure 1), elephant home ranges are very large, ranging between 1,000 to 5,000 km^2, depending on season. Observations by Höner et al. indicate that spotted hyena population densities can range from 0.5 to 2 adults/km^2 (2005, 549). Given a potential clan size of 43 agents (Höner et al. 2005, 546 table 1), territory size per spotted hyena clan can range up to $86km^2$ or more. Similar to hyenas, "prey availability and predation risk… influence fission-fusion dynamics of delphinids" (Pearson 2009, 1438). Another common trait that seems to unify the behaviour of these species is a shared utilization of elaborate communication systems.

For example, the vocal repertoire of bottlenose dolphins appears to not only convey individual identity but also group membership, as different whistle types have been observed to develop between groups within larger pods (Reiss et al. 1997, 142). Dolphin vocalization plays an important role during play as well as collective feeding (Van Parijs and Corkeron 2001) through which individual and pod identity can be conveyed. Hyena "laughter" is argued to encode agent-specific social information similar to that of primate calling or signalling (Mathevon et al. 2010). This is also true concerning elephant audible signalling. Soltis et al. (2005) note that changes in elephant ‘rumbles’ are used to signal emotional states as well as individual agent identities.

Primate examples:

In order to facilitate a larger discussion of social behaviour and organization within non-human fission-fusion communities, some of the organizational behaviours of chimpanzees, including bonobos, orangutans, and spider monkeys are reviewed below. As noted in the introduction, the social organization of *Pan troglodytes* was the first to be described as a fission-fusion system. Because of the long research history into the social behaviour of *Pan* (*Pan troglodytes* and *Pan paniscus*—pygmy chimps or bonobos) and their close genetic proximity to humans, chimpanzee sociality shall be discussed several times throughout this thesis.

The extensive and ongoing research directed at *Pan troglodytes* more readily allows a discussion of the situational conditions that affect pongid fission-fusion behaviour. Chimpanzees are known to modify their fission-fusion behaviour to tackle socially novel environmental conditions. For example, chimps in Bossou have been observed to form larger groupings “when in dangerous situations such as crossing roads” (Pearson 2009, 1438 citing Sakura 1994). To the same end, more is known about the variance in age and gender alliance among chimpanzees. Typically stereotyped as dividing into sex classes, Lehmann and Boesch note in their study of Taï Forest chimpanzees that with a reduction in territorial size “and fewer male, …chimpanzees formed larger parties more frequently, stayed longer in each party, and spent more time in mixed parties and less time in single-sex parties” (2004, 212-13). They further note that smaller community size results in a greater stability between age and sex classes and a reduction in the fissioning of groups. These examples suggest that social or interagent stressors as well as environmental conditions structure pongid fission-fusion behaviour.

Other primates like orangutans, although not a typical fission-fusion species (van Schaik 1999, 81), can offer insight into the social mechanisms that underpin aggregation events. This is particularly important as orangutans are often stereotyped as a solitary species when compared to other members of Hominidae (gorillas, both chimpanzee, and humans). A key reason for periods of orangutan gregariousness is to increase mating potential during female oestrus. In this case, females will actively seek out dominant males within a general range (van Schaik 1999, 76). The timing of fertility and sexual access appears very important. It has even been argued that females within gregarious primate species "induce suppression of reproduction in same-sex group members in order to force them to become helpers" (van Schaik 1999, 69) thus reducing the degree of intersex groupings and dependent offspring. In the case of bonobos and chimpanzees, female oestrus seems to drive the interaction time of females with males and thus mixed gender groupings (Furuichi and Ihobe 1994, 213). The prolonged period of oestrus on the part of bonobos may perhaps explain the greater degree of inter-gender interaction commonly observed among *Pan paniscus* (ibid).

For example, male conflicts within bonobo communities are less frequent, resulting in a smaller "repertoire of behaviours" concerning agonistic resolution (Furiuchi and Ihobe 1994, 224). The smaller degree of sexual dimorphism on the part of bonobos compared to chimps may explain why males do not form groups to control sexual access to females (Furiuchi and Ihobe 1994, 225) and may in part explain the reduction in the number of male conflicts while at the same time reducing the complexity of observed male-male social behaviour. In a study of wild bonobos in Wamba, Republic of Zaire, the spatially most cohesive dyads were "mother-son," followed by "brother" and then female based (Furuichi and Ihobe 1994, 214 figure 1). Thus consanguineal male alliances are not paramount in bonobo sociality. Contrarily to *Pan troglodytes*, young bonobos receive elevated social status as result of the presence of their mothers as well as the ranking of their mother within the group, and it also appears that change in the ranking of mothers directly affects the rank of their sons (Furiuchi and Ihobe 1994, 222).

Chimpanzee vocalization is thought to also convey individual identity and group membership, as in the case of dusky dolphins and elephants previously discussed. Laboratory trials, by Izumi and Kojima (2004), demonstrated that at least captive chimpanzees seem to exhibit a "crossmodel representation" of speech. In other words, chimpanzees utilize auditory and visual information in speech recognition – just as in human speech perception. Chimpanzees are not the only fission-fusion primate species noted to possess an elaborated system of vocalization. Spider monkeys (*Ateles* *geoffroyi*) are also argued to utilize vocalizations to convey agent information as well as to mediate interagent spatial proximity during foraging and social activities (Ramos-Fernández 2005).

The mediation of interagent spacing is very important among all fission-fusion species as it helps to reduce competitive behaviour. In their study of spider monkey communities in Costa Rica, Asensio et al. (2008) observed that subgroup size had a positive correlation with resource abundance and that higher rates of aggression occurred during feeding within large subgroups. Social regulation through aggressive behaviour appears to be a key mechanism in spider monkey fissioning, as Asensio et al. (ibid) note that female aggression toward subadults encourages fissioning, and thereby reduces food competition across the community.

Discussion

A further discussion of the social and organizational behaviours noted in the above review is necessary in order to further synthesize the examination of non-human fission-fusion behaviour. What appears common to fission-fusion species is the utilization of a dynamic group structure to overcome deleterious effects of environmental pressures on social cohesion, which is not an option for non-fission-fusion gregarious and solitary species. For example, Hyena clans have even been observed to fission to diminish social stress (Mathevon et al. 2010).

This capacity for a fission-fusion dynamic appears to have selected for an elaboration of certain social behaviours among the species reviewed. This seems particularly true for vocalization and display behaviour as well as sex and class organization. These commonalities deserve a more detailed discussion. It is also important to keep in mind the issues that diminish our ability to extrapolate or model specific social and organizational traits.

Vocalization and Display:

The complexity of fission-fusion behaviours requires a high degree of inter-agent tracking and often leads to the display of complex social signalling to reinforce social bonds. Though quite obviously the two inhabit very different environmental conditions, hyenas and dolphins share several prosocial behaviours that reinforce the stability of interpersonal partnerships that might otherwise be compromised by fissioning into small or solitary units. For example, spotted hyenas are known to "engage in reunion displays" (Smith et al. 2008, 620) where excitement over being reunited with allies is conveyed with both vocally and physically communicated cues. Delphinids will even engage in the use of naturally occurring objects such as seaweed as part of their prosocial behaviour (Pearson 2009, 1441 table 1). Hyenas have been observed to participate in conciliatory behaviours such as greetings and/or nonaggressive approaches (Smith 2008, 620).

Sex and Class Social Organization:

All of the reviewed species appear to exhibit some form of gender based exogamy. For example, the highest rate of aggression observed by Asensio et al. (2008) within spider monkey communities was exhibited by senior females toward migrating, subadult females. *Pan troglodytes* exhibit a similar pattern of female exogamy (Layton and O'Hara 2010). However, bonobos may perhaps present a less rigid age and sex class system compared to *Pan troglodytes*, placing less emphasis on female exogamy (Savage-Rumbaugh and Wilkerson 1978). Hyenas (Smith 2008) and elephants (Archie et al. 2008, 2667), by contrast, share a female or matrilocal social organization where juvenile males leave their natal communities in order to attain viable mating opportunities. Therefore, hyena and elephant species, despite crossing the herbivore/carnivore divide, share a very similar gender division in which the stability and maintenance of female social bonds dictate group cohesiveness. Common chimps (*Pan troglodytes*) by contrast maintain social cohesion through male alliance.

Some problems:

Though some fission-fusion species may share similar social superstructures, such as matrilocality, it is difficult to extrapolate from this information how organization at the inter-agent level plays out. For example, a form of gender divided exogamy is common to the fission-fusion species reviewed. However, it is problematic to define how similar trends in habitational systems relate to age and sex class alliances and courtship. Chimpanzees, dolphins, and hyenas exhibit sexual courtships with females (Connor and Whitehead 2005, 130), though these species do not share matrilocality. Chimpanzees, dolphins and hyenas will form intersex networks. In contrast, elephants do not form intersex alliances (Archie et al. 2008). Chimps and dolphins form male alliances whereas elephants do not (Conner and Whitehead 2004, 131). Further still, there is a high degree of variability between chimpanzee communities in regards to the formation of alliances among non-related individuals during task-based as well as social interactions. For example, male agents in a *Pan troglodytes* troop from the Taï Forest have been observed to "spend more than 80% of their time with unrelated conspecifics" (Lehmann and Boesch 2004, 208).

Further problematizing the ability to extrapolate, fission-fusion species will utilize fission-fusion behaviour in response to similar environmental stimuli to different effects. For example, chimpanzees are noted to limit foraging size to reduce the potential for large groups attracting predators (Pearson 2009, 1438) whereas dolphins will aggregate during seasonal migrations to form larger groups as an antipredator response (1443). Both the antipredator behaviours of chimpanzees and dolphins seem logical, and the specific scenarios are not fully parallel as the chimpanzee system is in response to predation risk in a closed forested environment. While, in contrast, the open waters that dolphins are subject to during their seasonal migrations present different risk factors. Nonetheless, the point remains valid that there is not a common rudimentary fission-fusion response that could predict the degree of fissioning or fusing from a single variable (such as, community fusing has a positive correlation to predation risk or fissioning would be anticipated during foraging/hunting activities).

To this end, it could be argued that chimpanzees and delphinids have essentially an inverted response in regards to their feeding behaviour. Chimpanzee fission-fusion behaviour is typified by fissioning into smaller units to exploit caloric resources whereas dolphins have been observed congregating to better exploit large schools of tuna, as previously discussed. In both the case of dolphins and chimpanzees the selective mechanisms that structure the fission-fusion behaviour of either species are nuanced. Utilizing biomass alone may not be the best measure of selective pressure on fission-fusion behaviour. Even factors as simplistic as resource abundance and resource patterning afford a more complete picture of the environmental conditions that shape the processes of community fissioning and fusing in relation to ecological carrying capacity.

This is because understanding resource abundance and resource patterning can be used to contextualize conditions that will produce scramble competition and conditions that will produce contest competition. To this end, there is an interesting trend in subgroup size among both spider monkeys and chimpanzees. When resources such as fruit patches become seasonally more abundant, subgroup sizes increase in both communities. Asensio et al. (2008) argue that this is a result of exploiting a high density and highly patterned resource. With this in mind, chimpanzee and dolphin fission-fusion responses to resource abundance and resource patterning appear very similar. The migration of large schools of tuna, results in dolphin aggregation. Likewise, seasonal increases in the size of fruit patches results in the formation of larger chimpanzee foraging parties. It is therefore the capacity to be flexible within the cohesiveness of communities that enables fission-fusion species to mitigate both scramble and contest competition.

Conclusion

This chapter has shown that the fission-fusion species reviewed possess a dynamic flexibility in social organization and subgroup formation. The problem then, for any researcher attempting to construct a unified or generalized model of fission-fusion behaviour, is that, at the base level, fission-fusion species may appear to present different utilizations of group structure in response to similar environmental pressures. However, resource availability and environmental risks are factors, especially in the form of resource abundance and resource patterning, which shape the socioecology of any species. Fission-fusion species have evolved this complex social dynamic to overcome or at least ameliorate the deleterious effects of these factors on the maintenance of gregarious systems. Though the exact responses may be different, the primary group response to environmental stimuli will be formulated through adjusting fusion-fission dynamism to overcome limiting environmental factors and social tensions that arise as a consequence. This is particularly true in the case of pongids and humans where "each individual has the option of associating with subgroups of different sizes" (Chapman et al. 1993, 31). The process of human fission-fusion behaviour is explored in the next chapter. In summation, the following synthesis of non-human fission-fusion behaviour is provided.

Synthesis:

1. It is difficult to pinpoint the exact ecological or subsistence patterns between species that may determine the formation of gender and class organization. For example, both hyenas and elephants exhibit a matrilocal organization despite being on very different ends of the trophic scale.

2. Chimpanzees (including bonobos) and bottlenose dolphins have been observed to form closed community groups.

3. Dusky Dolphins do not seem to exhibit territorial defence or hostility toward known pod members (Pearson 2009, 1438).

4. Therefore, territoriality does not always lead to hostile or defensive behaviour, however, mutual avoidance, as observed in sympatric delphinid pod behaviour, may present evidence for a non-hostile yet exclusionary behaviour.

5. There is one common socioecological factor that unites the species observed, a low population density. Low populations densities also relate to large annual ranges. For example, delphinid ranges far exceed any of the terrestrial species (this may be an effect of the limiting factor of terrestrial locomotion).

6. The variability in *Pan* group ranges should not be ignored "[t]he community range can cover an area from 5 km^2 to almost 300 km^2" (Symington 1990, 49).

7. There appears to be some degree of gendered patterning within all of the species examined. In fact, fission-fusion societies tend to formulate subgroups around gender and age groupings however bottlenose dolphins have been observed to form fission groups comprising up to three different generations (Reiss et al. 1997, 141).

8. Vocalization and paralanguage appears to have been selected as prosocial behaviours within all of the species reviewed. These forms of social communication are vital in the structuring of fissioning and fusing as well as reinforcing inter-agent alliance through reunification displays.

CHAPTER 4

Fission-fusion part II: human fission-fusion behaviour

Introduction

This chapter examines human fission-fusion behaviour as a mechanism for social alliance and conflict resolution as well as ecological adaptation. The objective of this chapter is to further contextualize this thesis within fission-fusion studies and provide further theoretical basis to the development of analytical methods used in this chapter to examine fission-fusion behaviour from the archaeological record.

As discussed in the previous chapter, there is variability in the fission-fusion behaviour of non-human species. Scramble and contest competition avoidance appear to be major factors that dictate the patterns and timing of the fission-fusion dynamic of the species examined. Like the non-human examples, there is a high level of diversity in human fission-fusion behaviour. For example, like their non-human counterparts, some hunter-gatherer communities will congregate around resource patches during seasonal shortfalls while others congregate during times of resource abundance. This seemingly diametric response may in fact be products of related environmental conditions. In this chapter, I argue that resource density and resource patterning are important factors that shape population density, annual average band size, and even the fissioning and fusing of bands.

Therefore, human fission-fusion behaviour may perform the same mechanistic function described in the previous chapter of mitigating scramble and contest competition among non-human fission-fusion species. In order to better contextualize this process, human fission-fusion behaviour is examined in regards to alliance and conflict resolution as well as ecological setting. This examination focuses primarily on hunter-gatherers, but ethnographic and archaeological evidence pertaining to communities that practice different modes of production are also discussed.

Human Fission-Fusion Behaviour

Hunter-gatherer social organization is often characterized as reflecting a fission-fusion dynamism in which agents disperse "on a daily or hourly basis from traveling or foraging parties" as well as aggregate into "equally temporary combinations" (Rodseth et al. 1991, 238). Though it may seem that with the diffusion of agro-pastoralism fission-fusion systems ceased to play a significant part in human sociality, both cultural anthropologists and archaeologists (Fix 1975; Blitz 1999) find it a useful heuristic in the analysis of 'small human populations,' such as swidden and subsistence farmers.

In fact, daily human routines, especially those in industrialized western nations, exemplify the deep rootedness of the fission-fusion behaviour of our species. The various comings and goings of the average household, adults going to their various places of work, children going to school often in separated classrooms, and the returning again at the end of the day are all components of a fission-fusion process, so common that they go unrecognized as such. Other social species that lack this capacity must perform their daily routines as one unit, maintaining the co-presence of all community members.

Fission-fusion alliance and conflict resolution

Marlowe (2005) notes that inter-agent tension creates problems above groupings of ~25 hunter-gatherers, the average number of individuals in a band community. For this reason, he suggests that fission-fusion behaviour is conditioned by social as well as ecological circumstances. Marlowe argues that the limitations of kinship bonds mean that existing affinal and consanguineal ties cannot overcome conflicts that arise within larger social groupings. Such conflicts may pose a greater threat to more sedentary and larger scale societies. Not surprisingly then, some sedentary communities have been argued to utilize a fission-fusion process in communal and political formation.

For example, Fix's (1975) analysis of agricultural societies reveals how fission-fusion behaviours are utilized to formulate alliance and mediate potential conflicts. His fieldwork was largely conducted among the Semai-Senoi, an ethnic community of swidden farmers from Malaysia. In his analysis of village formation, he makes several important observations concerning the structure of Semai-Senoi and Yanomamö village systems. The Yanomamö are an Amazonian ethnic group of horticulturalists that unlike the Semai-Senoi (Robarchek and Dentan 1987) have been noted for their practice of inter-village warfare (Chagnon 1988). Despite this difference, Fix (1975) notes that in both ethnic groups associations are sought with other villages through marriage and kinship alliance. Even though these villages can be described as semi-permanent settlements there is a preference for alliance and spouse selection at the inter-group level, which is a similar pattern to the one describe in the *band model* for hunter-gatherers. Similar to the stewardship of a band over a given territory, Semai-Senoi and Yanomamö villages comprise a socially defined and semi-permanent space.

However, living within this 'space' is fluid and subject to the formulation of extended networks that structure residency at the agent level. These alliance networks shape the movements and congregations of persons in both ethnic groups that occur within a fission-fusion process. Surprisingly, the effect of inter-village kinship proximity is different between the two cultural groups. The Yanomamö often demonstrate heightened levels of hostility between closely related kin whereas with the Semai-Senoi, kinship affinity normally dictates inter-village visits and seems to have no effect on the level of violence between villages, which is relatively minimal across Semai-Senoi society as a whole (Fix 1975, 297). Nevertheless, it is through preexisting kinship networks that the fissioning and fusing of Yanomamö and Semai-Senoi villages occur. Therefore, the formulation of kin based alliance between villages allows for the formulation of new villages as well as the fusing of existing settlements into larger settlements.

John Blitz (1999) argues for a similar fission-fusion process in the political formation of *Okla* in the famous Mississippian mound-building culture. An *Okla* was an individual farming community built around a centralized mound structure. Blitz describes the fission-fusion process of these polities in which the fission of an *Okla* can be seen as a mechanism of conflict mitigation and the fusing of *Okla* as an effect of intensive alliance formulation. Historically, *Okla* had an internal stratification between 'white' clans considered stable and long-lasting and 'red' clans considered unstable and short-lived. The "fission-fusion [of chiefdoms] created a white-senior:red-junior relationship" consistent across the *Okla* socio-political system (Blitz 1999, 585). The fissioning of an Okla was utilized, Blitz argues, to avoid conflict with competing hierarchical clans and families within individual polities whereas the fusing of two or more *Okla* created a federation capable of checking external hegemony.

The fusing of *Okla* was a complex process involving multiple levels of alliance and hierarchical status. Blitz notes historic accounts of twin *Okla* formation as well as the integration of 'refugee' communities into individual *Okla*. The joining or twinning of chiefdoms would result in some cases in a twin mound system where each community would perform their own ceremonial and political functions. This twin settlement system could result in equality between the two communities, but would often involve a hierarchical ranking. This asymmetric relationship according to Blitz may be archaeologically represented in the presence of twin mound sites where one mound is more substantial than the other. Twinning did not always result in the formation of twin or multiple mound sites, and historically *twinned* alliances seem more volatile with accounts of some twin *Okla* alliances breaking down into outright physical conflict. The inclusion of a 'refugee' community seems to have resulted in a pronounced hierarchical relationship with immigrant communities having to accept a "stinkard" or red clan status of subordination (ibid).

Blitz notes that the fission-fusion dynamic of these alliance systems resulted from internal response to both intra and inter-group pressure. In this way, it appears that the fission-fusion dynamic of the stratified Mississippian society mediates internal social stress in a similar fashion as that described for hunter-gatherers. Layton and O'Hara (2010) likewise note that a primary function of fission moments or aggregation events among their survey of hunter-gatherer communities is social exchange and the reorganization of band membership to mediate social tensions. Both aggregations and the general flexibility of band membership mean that fission-fusion processes can be utilized to reduce inter-agent conflicts. A key factor in inter-agent stress can be resource competition.

Robert Whallon (2006) suggests that the fission-fusion dynamics of hunter-gatherers acts as a system of indirect ecological or resource shortfall mitigation. Utilizing Birdsell's *equilibrium model*, Whallon (2006) argues that band movements and exchange at the inter-band and inter-regional level act as a type of delayed return investment wherein unpredictable resource scarcity can be mediated through social intensification rather than solely through resource intensification. To this end, preexisting alliances at can be called upon during times of resource shortfalls, allowing mutual access to resources between allied bands.

Whallon's argument highlights the fact that both social and environmental factors shape human fission-fusion behaviour. Environmental forcing seems particularly important in regards to the size and fission-fusion dynamic of hunter-gatherer bands.

Band Size and Ecology

As previously noted, there is a central tendency for bands to be composed of ~25 agents. This tendency is most apparent when looking at the averaged, annual band sizes. Nevertheless, there can be a significant degree of variability in band size between seasons and different environments (Table **4**).

Ecology	**Ethnic Group**	**Summer**	**Winter**
Tropical Forest	Mbuti Archers	15?	>60?
	Mbuti Net Hunters	>60?	15?
Semi-desert	Western Desert (Australia)	5-12	>100
Temperate Coast	Kwakiutl	50-60	
	Tlingit	<50	
Boreal Forest	Cree	15-50	
	Khanti	14	
Arctic Coast	Central Canadian Inuit	15-30	50-150
	Netsilik	20-30	50-100
Arctic Interior	Nunamiut	18-36	50-150

Table 4. Ecology and band size. Given the geographical range of the samples, 'Summer' and 'Winter' should be understood as loose terms designating the greatest seasonal differences. Data from Layton and O'Hara 2010, 88-9 table 5.1 and review below.

Like demography and territorial size, variations in the composition of bands seem largely dependent on ecological context. This becomes clearer upon closer examination of band formation among different hunter-gatherer communities.

Mbuti:

The Mbuti are an ethnic community of hunter-gatherers that inhabit the Ituri tropical rainforest located in the Democratic Republic of the Congo. There has been a long history of ethnographic research on the Mbuti some of the most seminal of which being Turnbull's 1960's publications. In these, he argues that Mbuti bands could be divided according to subsistence regimes into groups of net-hunters and archers (Harako 1976). This division was the cornerstone of Turnbull's (1965) *flux* hypothesis. According to this hypothesis, the lax ecological pressures of the Ituri tropical forest enabled the Mbuti to develop at least two different subsistence behaviours within the same niche, hunting by bow and hunting by net. Net hunters and archers practiced different aggregation and dispersal behaviours, which Turnbull interpreted as suggesting that Mbuti fission-fusion behaviour was a product of socio-political or interpersonal tensions rather than ecology. However, Abruzzi (1980) has argued that this *flux* is in fact the result of economic and ecological realities that were unrecognized by Turnbull.

Abruzzi suggests that Turnbull's social thesis overlooks important ecological and economic factors. The crux of the argument for both Turnbull and Abruzzi is what forces produce organizational differences during the 'honey season' when net hunters disperse into smaller social units and archers congregate into larger groupings. Abruzzi argues that the variability between the two Mbuti systems is a product of living in proximity to agriculturalists that inhabit the periphery of the Ituri Forest. The archers live closer to these farming communities and are more reliant on trade with them for a significant portion of their caloric resources. The net hunters by contrast have less contact with agriculturalists and therefore are more self-reliant.

During the non-honey season, food resources become more scarce and net hunters band together around available food patches, working cooperatively in net hunting activities. During the honey season, there is a general increase in caloric resources and the net hunters are able to disperse into smaller groups throughout the forest. By contrast, the archers rely on their preexisting relationship with agricultural communities to compensate for general reductions in caloric resources. This means that the archers must fission into smaller family units to live with and work alongside the agriculturalists. The archers congregate to maximize their exploitation of honey and wild game and thus maximize their trading value with the agricultural communities. Farmers may even journey out to live with the Mbuti for short periods of time (Terashima 1998).

Abruzzi's depiction of the Mbuti is mirrored in other works. For example, Ichikawa (1979, 6) notes that in the Tetri region, where Turnbull worked, the Mbuti did not practice much bow hunting, but preferred net and spear hunting. In fact, Ichikawa (1983) argues that the Mbuti subsistence regimes would be untenable without trade with agriculturists, suggesting that prior to the encroachment of swidden farmers, the Mbuti hunting and foraging activities must have been much more intensive. Hart and

Hart (1986) came to a similar but more detrimental conclusion for Turnbull's *flux* argument. Their assessment of the annual availability of caloric resources in the primary forest zones of the Ituri indicated significant seasonal shortfalls, leading to the conclusion that the interior of the rainforest would have been nearly uninhabitable for the Mbuti prior to established trade with agriculturalists.

Therefore, Turnbull's net hunters could be argued to better represent the subsistence regimes and fission-fusion behaviour of Mbuti ancestors prior to the development of more complex economic relationships with agriculturalists. The net hunter pattern suggests that resource density and abundance play heavily in the fission-fusion process and annual variance in band or cohabitation size. When resources abundance is low, reduced to a few clusters, smaller bands fuse around them. As resource abundance increases and patterning decreases when the 'honey season' comes, these larger aggregations fission into smaller bands, dispersing in order to effectively exploit available resources.

The Mbuti archer system could be read in a similar light if the economic relationship with neighbouring agriculturalists was looked at as simply another environmental resource. Residing with agriculturists could be viewed as a low patterned high resource environment, the community fission into family units to reduce scramble competition and defuse potential social tensions that could arise between themselves and the farming community. When the honey season commences, archers congregate and journey into the forest establishing base camps to maximize the exploitation of forest resources in order to generate a surplus that can be traded with the agriculturalists. Honey is the main target of this semi-economic or trade driven exploitation of forest resources, which could be argued to be a patterned or clustered resource.

Tlingit:

The Tlingit are an ethnolinguistic group that historically inhabited the temperate coastal zones of south-eastern Alaska (Thornton 2011). Some Tlingit communities, such as the Tagish, Atlin and Teslin *bands* (McClellan 1953), inhabited more interior environments. The subsistence practices of these inland bands were primarily directed at exploiting salmon along the Yukon and other Alaskan riparian zones (VanStone

1976). Along with other pacific north-western native groups, the Tlingit are often described as complex hunter-gatherers due to their systematic and technologically demanding exploitation of marine and coastal resources (Fitzhugh 2003). The Tlingit are particularly noted for the elaborate nature of their subsistence practices, which involved various technologies for the catching and storage of aquatic resources (Langdon 2006). They are further known for their ownership of *clan* or band territories and complexity of social stratification (Thornton 1997), resulting in a settlement pattern that is largely sedentary.

The stability and productivity of the environmental context in which they live has been linked with the complexity and elaborate gender division of exploitation activities among the Tlingit (Jochim 1988, 131). Rowley-Conwy (1982, 533) argued that the subsistence and organizational pattern typified by the Tlingit is in large part a product of the riparian and coastal ecologies of southern Alaska and Pacific Canada where caloric resources are “both seasonal…and abundant.” This appears to have enabled the formation of larger and more stable bands. For example, Layton and O’Hara (2010, 86 table 51 citing Emmons 1991) list the size of Tlingit bands as including up to 50 individuals. They list population densities between 0.4 and 0.77 (ibid), which are the highest out of Layton and O’Hara’s survey of twenty-seven hunter-gatherer groups.

Contact with European powers cannot explain the ‘complexity’ of Tlingit subsistence strategies or sedentism. For example, Ames (1994, 218-9) observes that the archaeological record for sedentism starts at least three thousand years ago along the Pacific Northwest with evidence for the construction of longhouses and other structures known from 19th century accounts of coastal villages. This suggests that band size and composition were fairly stable with a village system that extended back several thousand years. In fact, the demographic size of the Tlingit community posed a serious obstacle to Russian advances within southern Alaska. Beyond the existence of multiple villages, the Tlingit had a well-established system of fortifications capable of withstanding European military advances that predated western contact (Moss and Erlandson 1992). Significant battles occurred with the Russians during the first decade of the nineteenth century (Foster and Henrikson 2009) and with the United States in the late 1860’s (Jones 2013).

It seems then that prior to western contact, population densities were very high and band sizes were relatively large and cantered around sedentary villages. This pattern was mirrored in the social organization of neighbouring cultural groups. Jochim (1988) and Rowley-Conwy's (1982) suggestion that a common ecological setting fostered this cultural system seems salient. This is because the patterned and abundant resources of the temperate coastal margin enabled Tlingit bands to fuse around seasonally predictable caloric clusters.

Being abundant and highly patterned, the Tlingit could exploit coastal resources in such a way that would result in surplus (Langdon 2006). The storage of surplus caloric resources may have led to reductions in mobility, encouraging greater sedentism (Testart et al. 1982). Nevertheless, the general richness and seasonally predictable nature of resources would have allowed for high population numbers and larger band sizes. It therefore appears that in the case of the Tlingit a large part of their band organization, particularly their larger than average band size and very high population densities, were the result of their ecological context.

Khanty and Cree:

Though originating from different continents, both the Khanty and Cree inhabit taiga/boreal forest environments. The Khanty are a group of hunter-gatherers and semi-pastoralists that inhabit the taiga environment surrounding the Ob river system in central Siberia (Jordan 2001). The Cree are one of the primary First Nation groups of Canada's boreal forest zone (Berkes and Davidson-Hunt 2006, 37). Both groups share a comparable band organization, including similarities in their population densities and local community sizes.

The Cree and the Khanty have the lowest population densities within Layton and O'Hara's sample at 0.004 to 0.005 persons per km^2. Likewise, bands in both groups are centred on family networks. Both the Khanty and Cree are known to subsist on woodland Caribou/Reindeer. The Khanty live in extended family groups that occupy hunting grounds that are considered nearly exclusive to the resident family (Wiget and Balalaeva 2001, 84). It has been generally assumed that Cree settlement patterns were shaped by a similar system of family owned hunting territories (Speck 1915), but this is a major area of debate (*for a retrospective review, see* Pulla 2011).

The Khanty are typically described as semi-nomadic (Jordan 2001) while George et al. (1996, 356) describe the traditional Cree settlement pattern as one of “scattered local bands”. The number of individuals that comprise Khanty bands averages to ~14 agents while Cree bands average a comparable 15 agents (Layton and O’Hara 2010, 86-7 table 5.1). Khanty family size on average is about eight individuals (Jordan 2003, 71), making a typical range of 10 to 32 individuals at each yurt, or residential camp, with divisions into groups of eight individuals to exploit caloric resources. Likewise, there is a degree of variability in Cree band size with some local groups ranging up to 50 agents (ibid).

The limitations of living within the boreal zone may explain the similarities in the band or local groups patterns of the Khanty and Cree. Layton and O’Hara (2010) suggest that the boreal zone is an unusually difficult ecological zone for hunter-gatherers. Winterhalder (1981, 67) notes that there are multiple historic accounts of shortcomings in food resources and community starvation among Cree communities within the boreal zone. Boreal reindeer, a primary prey species, are also not particularly abundant. For example, Wiget and Balalaeva (2011, 11) observe that taiga reindeer herds are significantly smaller and have more limited seasonal rounds compared to their tundra counterparts.

There is of course variability in both Khanty and Cree band sizes. The fact that this variability in band size exists only helps to substantiate the fact that band organization is a fluid adaptation to local ecological contexts. For example, in both the Khanty and the Cree, larger band sizes are recorded in areas were settlements occur along major riparian zones such as the Ob and its main tributaries in the Khanty case. In these areas, organization and local group size are more reflective of the Tlingit organizational patterns than other Khanty or Cree groups. For example, band sizes among the James Bay Cree are largest in winter when multiple households will band together for communal fishing and trapping activities (Scott 1986, 166-7). Khanty communities along the larger fluvial systems of the Ob’ River live in larger, sedentary villages while in contrast the Khanty that inhabit the boreal forest live in small units of “two to four households” that further divide into even smaller units to exploit “areas of economic interest” (Jordan 2001, 85).

It appears that larger band size amongst the Khanty and Cree are limited to those groups that inhabit riverine and other aquatic zones. This is due to the fact that these zones offer resources that are both abundant and seasonally patterned, enabling the accumulation of surplus goods. By contrast living in the taiga/boreal forest zone does not afford such resources. The low resource abundance and lack of resource patterning in boreal forests results in small, stable band size in the majority of Cree and Khanty communities. The wide spread distribution of small local groups amongst both communities reflects a similar process of scramble competition avoidance that was discussed in the previous chapter for non-human, fission-fusion species.

Western Desert Cultural Group, Australia:

The Western Desert cultural bloc covers some 600,000 km^2 of arid land in western and north-western Australia largely inhabited by various aboriginal communities (Dousset 2008, 265). Gould (1969) notes that contact with these aboriginal groups was limited prior to the late nineteenth century. It was not until the 1950's and 1960's that the traditional settlement patterns of the Western Desert were disrupted by the government, sponsored relocation of communities onto mission settlements (ibid, 255-6).

Population densities throughout the Western Desert range between 0.01 to 0.02 persons per km^2 (Layton and O'Hara 2010, 86-7 table 5.1). Average band sizes range between 6-30 individuals (ibid), however, there is greater degree of diversity in local groups or cohabitational unit size on an annual basis. The true range reflects a high fission-fusion dynamic with local groups fissioning into almost nuclear family sized units and fusing into aggregations up to 150 or more individuals.

This pattern is seen in the sociality of the Walbiri, an archetypal Western Desert community, of the Tanami Desert. The Walbiri, being an ethnolinguistic group, are divided into several scattered communities. These communities are composed of extended family networks. Meggitt (1966, 174) observed that there was a high degree of variability in band size throughout the year with family groups between five to twelve persons comprising the base level of social organization. Seasonal changes in caloric and water resources were seen to be prime movers in annual band organization with maximum cohabitation size ranging from family units to nearly the whole community of over 150 individuals (ibid).

The dispersal of family groups among the Walbiri occurs "along strings of sacred sites" that are nominally controlled by individual bands or families, but open to all members of the larger community (Godelier 2012, 165). Berndt (1959, 96-7) observed that patrilineal descent was commonly practised throughout Western Desert communities. Male rights to the territory of their paternal kin was not simply guaranteed by birth, but by being born next to 'totemic' localities (ibid). Unlike the pattern of Mbuti net-hunters, Walbiri bands split into family groups during times of resource scarcity. During the rainy season, the filling of large waterholes enables the congregation of several family units, amounting in some cases to hundreds of individuals (Beaumont 1993, 77). The Gugadja of the Great Sandy Desert present a similar pattern to the Walbiri. The general pattern of their band organization is focused around extended family units with stewardship over given localities. Concentrated periods of rain lead to increases in game and floral resources, enabling the aggregation of extended family groups into large cohabitation units comprised of over 100 individuals (Cane 1987).

The Western Desert system reflects a dynamic fission-fusion process. This dynamism is in large part a product of the ecological conditions of Australia's western deserts. Seasonal differences in these deserts are quite significant, with major shifts in the size and distribution of watering holes, temperature (the extremes between the highest annual day and lowest night temperature can be as great as 40° C), and major differences in food availability (Cane 1987).

The rainy season transforms portions of the Western Desert, a typically low abundance environment, into areas of concentrated resource patches. Local groups or bands that foraged within extended family networks possess a kind of recognized stewardship over a territory defined through a 'constellation' of sacred places. Despite band territories being understood in terms such as 'my country' (Berndt 1959, 97) inter-band territorial access is permitted within the *regional community*. This mutual access has a mechanistic function that enables the aggregation of several local groups during the rainy season (Gould 1969, 256).

Discussion

Human fission-fusion behaviour can be used as a mechanism for social alliance and conflict mitigation. It is also a mechanism that enables human communities to adapt to specific ecological conditions. Layton and O'Hara (2010) emphasize how fission-fusion processes in hunter-gatherer communities enable aggregation moments, providing time and space for marriage arrangements and the reorganization of band membership. Marlowe (2005, 59), on the other hand, emphasizes how the fission-fusion aspects of hunter-gatherer societies mitigate intra-community stress such as "conflicts between families" through the fissioning or disbandment of local groups.
Fix (1975) observes similar processes in Semai-Senoi and Yanomamö village fission-fusion patterns. His work suggests that, like hunter-gatherers, internal social tensions among small farming communities necessitate the formulation of kin networks beyond the local group in order to provide a system of preexisting alliance and relationships from which new cohabitation patterns can be formulated.

The fission-fusion dynamic of *Okla* appear analogous to similar processes described for hunter-gatherers and small-scale farming communities. A common cause of an *Okla* fissioning was internal social stress and inter-agent conflict. Therefore, a general assumption that fissioning acts to mitigate conflict and diminish the impact of internal stress on the viability of a community as a whole seems salient. Conversely, external pressures, especially in the form of competing communities can promote fusion. The external pressure in the case of the Mississippian society came from competing Amerindian communities and encroachment by white settlers. Marlowe notes that hunter-gatherer bands will also fission to form larger defensive groups to handle the "prevalent warfare" of neighbouring groups (2005, 59). To this end, both Mississippian and band hunter-gathers practice moments of community fusing to mitigate external stressors. By forming twin alliances or by absorbing a 'refugee' group, an *Okla* community made an insurance investment against future external conflicts.

The investment in alliance through the fusing of two *Okla* mirrors Whallon's hypothesis of inter-band alliance among hunter-gatherers. However, Whallon (2006) argues that inter-band alliance is only adaptive in environments that support heterogeneous ecologies. The brief review in this chapter of alliance behaviour within various types of human sociality systems suggests contrarily that environmental heterogeneity alone cannot predict inter-group alliance. Even though inter-band alliance may indeed help to mitigate resource shortcomings within band territories through a form of social intensification, there appears to be a general human tendency to formulate extended social networks beyond the local group. The same reasoning means that cultural intensification/*complexity* cannot account for or necessarily predict fission-fusion processes. This suggests, as Whallon argues, that environment may nevertheless play a pivotal role in the timing and dynamic of fission-fusion behaviour while at the same time the social aspects of this process should not be ignored. The use of *closed* and *open* communities as an explanatory framework contributes to the perceived dichotomy between social and environmental pressures.

For example, Gamble (1999) divides literature dealing with early human sociality into two camps, one that supports an assumption that communities were ‘closed’ and the other that they were ‘open’. *Closed societies* are thought to have smaller, highly defended territories with greater individual *ownership* over resources whereas *open societies* are assumed to have larger more porous and undefended territories, lacking individual or family *ownership*. The former conform to the seminal work of Julian Steward on the Owen’s Valley Paiute while the latter follow Richard Lee’s description of the !Kung San.

However, comparisons between bands or local group organization must be placed within the context of environmental conditions. For example, Steward’s Owens Valley Paiute ‘band’ is not a comparable social unit to the bands of Lee’s !Kung San. Rather these differences are the result of ecological structuring of band size or more permanent cohabitation groups. In this case, the Owens Valley Paiute ‘band’ is better understood as a *regional group* with a cooperatively defended territory much like any other hunter-gatherer community. San ‘bands’ are more readily recognizable as a *band*, but their ‘openness’ is the result of the cross-culturally observable flexibility of band membership and permissive access to band territory between members of the larger *regional group*/dialectical body. It is, therefore, the unique environment of the Owen’s Valley fluvial systems that creates a level of resource abundance and patterning that enables larger more sedentary local groups whereas the low resource density of the Kalahari means that social networks are stretched out over large areas.

Within a *band model* framework, the Owen's Valley Paiute and Kalahari San systems are better understood as different modes within a common spectrum of fission-fusion behaviour. Two of the most important factors that influence the mode or expression of a hunter-gatherer community's fission-fusion dynamic are resource abundance and resource patterning. These factors seem to effect human fission-fusion behaviour in an analogous manor to that of non-human fission-fusion species.

As discussed in the previous chapter, the abundance and patterning of resources dictates scramble and contest competition. Fission-fusion social behaviour has a mechanistic function that mitigates scramble and contest competition through enabling flexibility in group cohesion. By viewing hunter-gatherer band formation as the result of an analogous process, a model of hunter-gatherer local group formation and mobility relevant to archaeological investigation can be developed. Hunter-gatherer band formation deserves further discussion before a model of local group formation and mobility/settlement can be outlined.

As we have seen, there is a general tendency for bands to be composed of 25 agents. However, as reviewed earlier in this chapter, there can be significant differences in the numbers of cohabitating agents between different hunter-gatherer communities. Factors that relate to these differences are seasonal and ecological patterns. However, the presence of seasonal patterns alone cannot affectively account for the complexity of local group formation and settlement patterns.

For example, annual community aggregations are observed among both the Mbuti net-hunters as well as Western Desert aboriginal communities, resulting in large band/local group sizes during these periods. As previously discussed, this is despite the fact that Mbuti aggregation occurs during times of lower resource densities while aggregations in the Western Desert coincide with seasonal increases in resource densities. This discrepancy is explained when resource patterning is taken into account. In both examples, resources, whether scarce or abundant, are patterned or patchy. The human tendency to aggregate around patches of resources reflects a common fission-fusion species response to environmental conditions. Nevertheless, overall resource abundance affects carrying capacity and thus population densities. Therefore, it is both the patterning of resources as well as abundance that dictates variance in hunter-gatherer local group formation and settlement patterns.

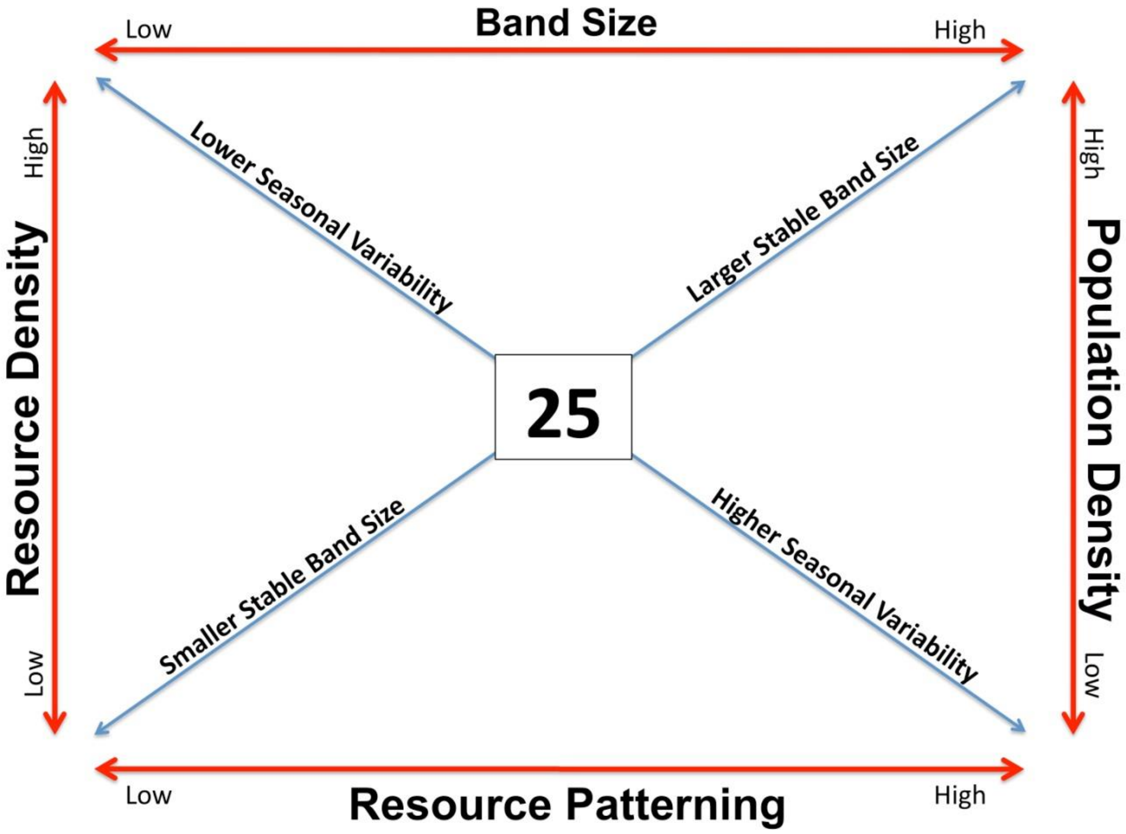


Figure 22. Modelled relationship between band and population density and resource density (abundance) and resource patterning.

The ethnographic examples reviewed in this chapter suggest a significant correlation between resourcing patterning and density with band size and population density (Figure **22**). Resource density has a positive correlation with population density, but does not necessarily have a positive correlation with band size while resource patterning does have a positive correlation with band size. The interplay of resource patterning and density affects settlement patterns and the dynamic of cohabitation size throughout the year. High resource density and high resource patterning appears to result in larger local groups that are stable as in the case of the Tlingit. High resource density and low resource patterning can be anticipated to result in lower seasonal or annual variability in band size while low resource density and high resource patterning should result in higher seasonal variability as in the case of Western Desert Aboriginal groups. Low resource density and low resource patterning seems to result in small stable local groups as in the case of the Khanty and the Cree. Looking at a larger number of hunter-gatherer cases (Figure **23**), a relationship between band size and ecological is visible.

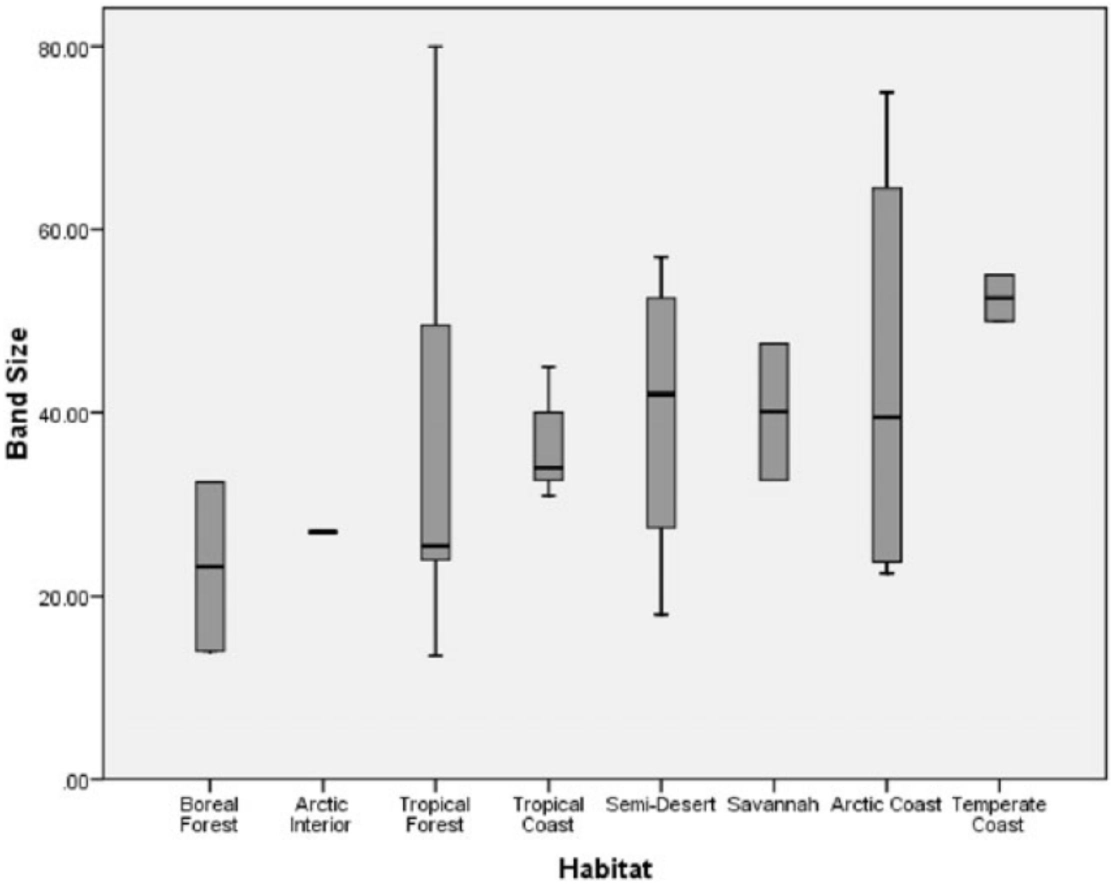


Figure 23. Variation in band size depending on ecological setting for twenty-seven different hunter-gatherer societies. Graph copied from Layton and O'Hara 2010, 93 fig. 5.2 (b).

There is clearly variation in band size that can be differentiated by ecological context. These examples mirror the ethnographic cases examined in this chapter (Figure **24**). The greatest differences in band size exist between the boreal forest and temperate coastal ecologies, however, average band size in the remaining cases appears to fall between these.

Human fission-fusion behaviour appears to mirror that of other fission-fusion species in that it mitigates social stress and enables communities to adapt to differences in environmental resource distribution through the utilization of a unique social capacity for elastic social cohesion. In effect, social stress and environmental forcing can be seen as having a dialectical or interactive relationship, contributing to the variation in sociality modes seen between different human communities.

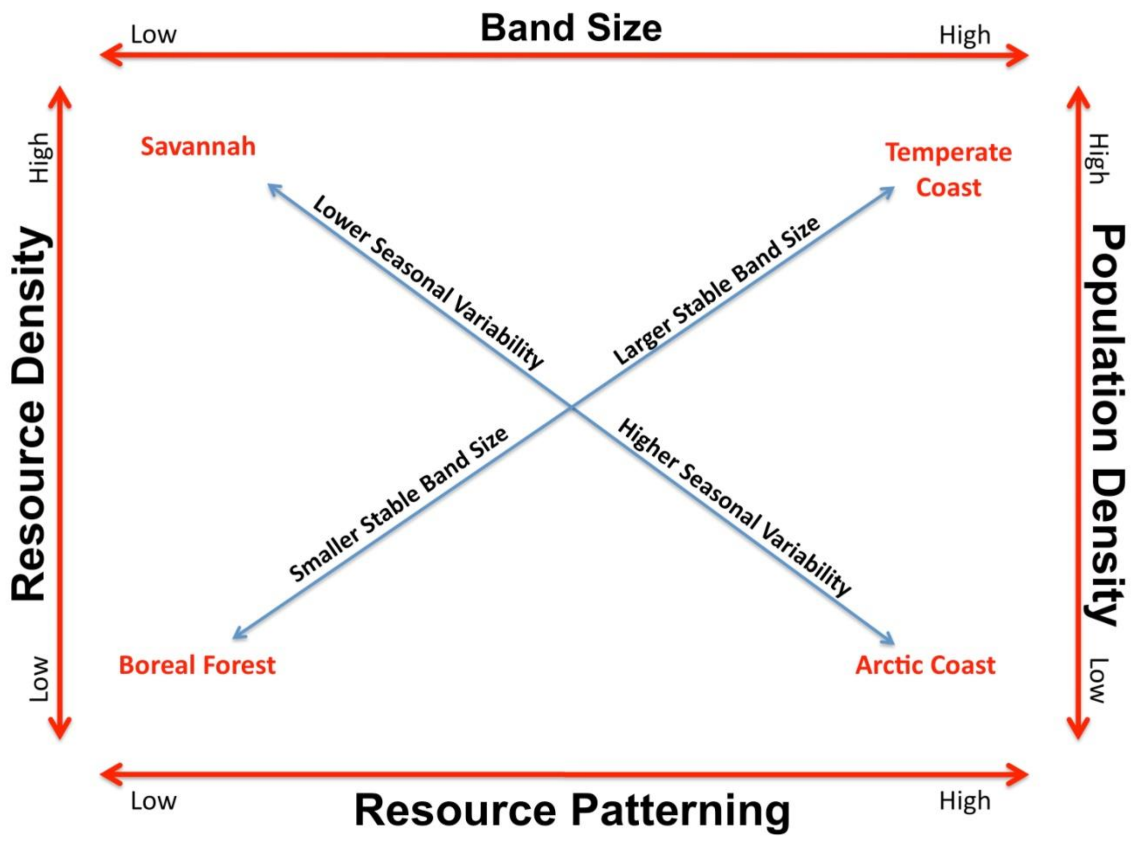


Figure 24. Placement of four of the ecological cases from graph 1 within the modelled relationship between band and population density and resource density (abundance) and resource patterning.

Flight and scramble competition as a primary selective force in human and non-human fission-fusion behaviour suggest that both ecological context and inter-group social stress play a significant role within species variation of community organization. This is because the abundance and patterning of resources leads to different competitive pressures between group members. Fission-fusion species manage these pressures through a flexible cohesiveness that enables a fissioning of the group when resources are scarce and widely distributed. Likewise, fission-fusion mechanisms allow the group to aggregate or fuse around resource patches in order to ameliorate contest competition that would only benefit a few individuals. At the same time, aggregating around resource patches enables the community to effectively defend these resources from non-community members.

Conclusion

The aim of this chapter was to better contextualize how human fission-fusion behaviour affects alliance and conflict mitigation as well as adapt community organization among hunter-gatherers to environmental conditions. The band model recognizes that fission-fusion behaviour is a mechanism employed to mitigate both social as well as environmental stress on community cohesion. Variability between the band organization of different hunter-gatherers appears to be an effect of a common fission-fusion mechanism that allows communities to adapt to differences in resource abundance and patterning.

This variability is highly significant for its archaeological implications. If such variability existed in the past, this could have had a significant effect on the formation process of archaeological residues most particularly, the quantity, diversity, and distance of raw materials deposited at sites as well as the size of living or surface areas. If this is true, then site to source distance cannot simply be seen as a proxy for exchange and network size or complexity.

The following chapter examines both anthropological and archaeological research into the evolution of modern social behaviour to further contextualize the *band model* within related studies.

CHAPTER 5

Theoretical background part I: alliances, the transition from troops to bands, and magic numbers

Introduction

This chapter contextualizes the band model within existing literature on the evolution of human sociality. This entails a review of Birdsell's equilibrium systems theory from the 1966 Man the Hunter symposium as well as a discussion of theories concerning alliance systems, ideas about the transition from troops to bands, and evidence for multilevel organization. I argue that the band model is unique in that it does not argue for a drastic change in the course of human social evolution, but rather sees human social complexity as an elaboration of deeply rooted fission-fusion behaviour within Hominidae.

The previous chapter outlined the field of fission-fusion studies and some aspects of non-human and human fission-fusion behaviour. Layton and O'Hara (2010) embed their *band model* within the socioecological context of existing fission-fusion studies both within hunter-gatherer studies and primatology. For this reason, Layton and O'Hara (2010) and Layton et al. (2012) are highly informative in the investigation of sociality patterns within the archaeological record of the Middle and Upper Palaeolithic. This chapter looks more closely at other existing literature about the evolution of human sociality in order to deepen the theoretical context of the thesis. This is done through a review of anthropologically based as well as archaeologically based studies about the evolution of multilevel organisation and fission-fusion (aggregation and dispersal) dynamics.

Birdsell and Equilibrium Systems

The explicit discussion of multilevel organization within human communities owes much to Lee and Devore's 1966 *Man the Hunter* symposium. One of the key works to come out of this was Birdsell's *equilibrium systems* model of social organization during the Palaeolithic. Birdsell's initial concern was with the socioecological conditions of hunter-gatherer carrying capacity and demography (2009).

In the hope of producing accurate and testable assumptions about human social systems during the Pleistocene, Birdsell extended his analysis of equilibrium systems to encompass the function of communication, subgroup organization, and consanguineal kinship within hunter-gatherer societies. Birdsell had previously established an associative link between annual rainfall and "tribal territories" (ibid, 230). From this research, he concluded that hunter-gatherer societies live at an equilibrium density, implying that these communities functioned at "the approximate carrying capacity of [the] environment" (ibid).

Though population density may be dependent on the carrying capacity of a given territory, the internal structures of a population and even the boundaries of a community are not necessarily a function of carrying capacity *per se*. Here, Birdsell argues that dialectical boundaries best describe the division between different hunter-gatherer communities. Further, these linguistic units were noted to be composed of about 500 agents on average (ibid, 232). This observation led Birdsell to argue that dialectical bodies are an emergent property of the level of inter-agent dialogue in terms of "intensity", "frequency," and "duration." Hunter-gatherer communities are thus units that "maximize population survival" (ibid, 234). He argued that dialectical groups were subdivided into subgroups as conditioned by environmental and ecological circumstances.

These subgroupings were argued to be composed of interrelated nuclear families that typically average about 25 individuals. Birdsell was careful to note that this number is variable and dependent on local resource concentrations. Therefore, in areas of higher natural abundance, "local groups" can be composed of 100 or more agents. The spatial concentration of resources and general resource abundance was noted by Birdsell as being the greatest determinant in the demographic variation observed between subgroups within a community as well as between communities. Birdsell's final concern was with the parameters of reproductive equilibrium within hunter-gatherer societies. He assumed that dialectical groups already existed at a state of demographic equilibrium with environmental carrying capacity. His reading of ethnographic data indicated that "intertribal marriage," marriage between dialectical communities, was rare. This led Birdsell to the conclusion that hunter-gatherer communities also formed reproductively stable units.

Implications to understanding Pleistocene social systems

Throughout his discussion, Birdsell offers a number of predictive assumptions concerning Pleistocene social systems. Several of these assumptions are highly relevant to the current discussion and can be divided into the two categories: structural organization and environmental determination. The works of Marlowe (2005), Layton and O'Hara (2010), and Layton et al. (2012) mirror Birdsell's structural-functional predictions for Pleistocene social organization.

Community organization:

As previously discussed, Palaeolithic communities are anticipated to conform to dialectically differentiated units with a demographic equilibrium state of ~500 agents. These dialectical units will be subdivided into local groupings numbering ~25 agents. Exogamy should be preferred at the "local group" level while endogamy should be preferred at the dialectical level. As such, effective reproduction should conform to a limited "breeding population" roughly akin to the dialectical body (Birdsell, 2009, 239).

Environmental and ecological forcing:

Environmental factors should best predict variance within and between Pleistocene community systems. The affect of environmental variables will of course demand their own cultural responses. According to Birdsell, cultures are reactive to environmental stimulus. Therefore, variability in the structural organization of communities is seen as products of sociobehavioural responses in order to restore equilibrium at various levels within a social system.

"[C]hange [in] biotic, climatic, and technological variables" (Birdsell 2009, 231) are argued to have had the greatest impact on the structure and territoriality of dialectical bodies. In this regard, environmental forces would have the greatest impact on demography and structural organization during the Pleistocene. Ecological decline is assumed to directly correlate with demographic decline. If such declines were short-lived, the natural level of human fertility would restore population equilibrium within a generation or two. Birdsell notes that this process would be nearly invisible archaeologically (2009, 231).

The subunits or local groups are anticipated to conform to the general demographic trend (~25 agents as noted above) however the demography and settlement pattern of these units should be more greatly subject to environmental variability than the dialectical body. “[L]ocal groups will take on a very different nature” (ibid, 235) as a result of different patterns in the concentrations of resources in both general and seasonal terms. The importance of Birdsell’s assumption is that local group organization and size is anticipated, to a significant degree, to be variable in terms of territoriality and demography. By contrast, dialectical community sizes should be uniform, as the number of agents required to maintain an effective endogamous body would regulate them.

Layton and O’Hara (2010) and Layton et al. (2012) have many common points with Birdsell’s *equilibrium systems* model. The most important of these is the recognition that hunter-gatherer societies are multilevel in nature and can be stereotyped into bands comprising ~25 individuals and a larger community of ~500 agents. Likewise, they recognise that hunter-gatherer communities can often be defined as dialectical units. They also argue that hunter-gatherer demography is subject to ecological structuring and that such a process would have to have also applied to Pleistocene communities. These points deserve further consideration specifically in regards to questions and ideas raised within existing literature about:

- Social alliance as a mechanism for group formation
- Arguments about the transition from troops to bands within the course of human social evolution
- Evidence for social groupings during the Palaeolithic.

Alliance and social evolution

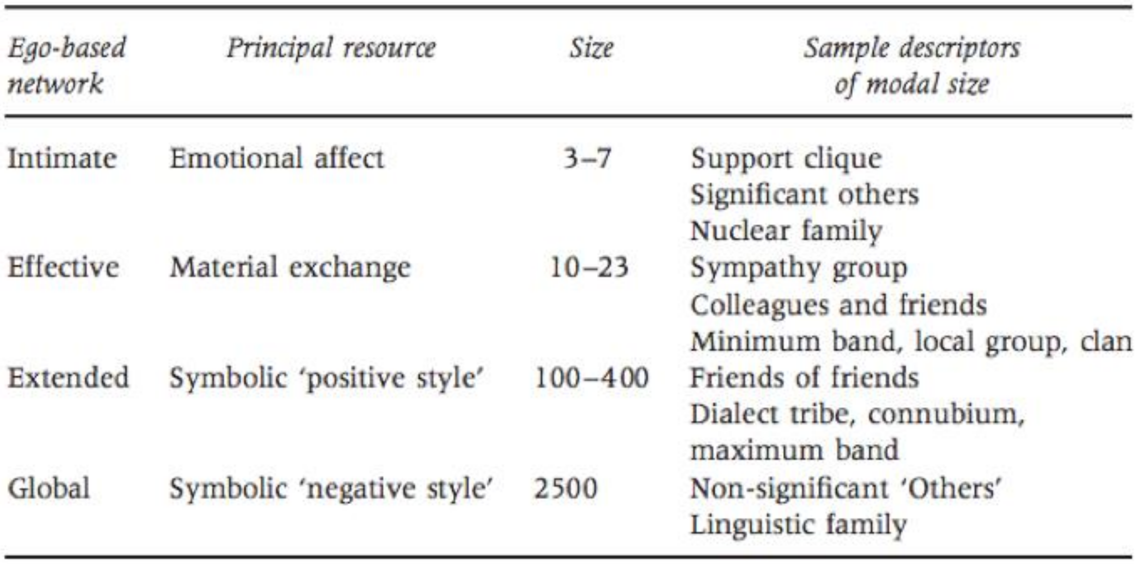
There are several social mechanisms argued to enable or allow the formulation of inter-band alliances such as marriage or fictive kinship systems to ego-based social intelligence. These arguments hold in common the idea that larger communities, such as dialectical bodies, are products of alliance systems. However, the capacity to employ such mechanisms is argued to have been the result of either social selection or environmental selection.

Alliance as a product of social selection:

One very influential idea has been the *release from proximity* concept espoused by Rodseth et al. (1991). In their attempts to specify uniquely human social conditions, they focus on the human tendency toward lifelong kinship roles and the “dynamics of the human community… that distinguish human from other primate groups” (ibid, 223). They argue that this dynamic denotes a social capacity that is truly unique to humans as a species, the ability to formulate and maintain interpersonal relationships “in the absence of spatial proximity” (1991, 239).

Rodseth et al. (ibid, 240) coin the capacity to perform social acts in absentia as the “release from proximity.” Ritual behaviour is meant to subvert the praxis of multilevel organization, allowing a moment in time and space where an “ultra-sociality” or a face-to-face human “troop” emerges that is devoid of the internal social division for which the human community can be typically described. Therefore, ritual and symbolic behaviours are seen as a mechanism to mediate tension that builds between the familial/stable unit and the greater community. This extends between subgroups and across all levels of social organization. Ritualized behaviour or communal ceremonies neutralize this tension in a particular point and time in space in which the multilevel community gives way to “a seamless social whole” (ibid). They argue that removed from the formulation of multilevel organization and fission-fusion dynamic of human sociality, ritualized communal behaviour or *communitas* would not have evolved.

The concepts of *communitas* and release from proximity have been very influential in the field of Palaeolithic Archaeology, especially in the work of Clive Gamble (1998; 1999). However, Gamble (1998; 1999) has favoured a more fluid agent or ego-based formulation of alliance perhaps informed by Murdock’s (1971) critique of over-arching ‘social systems’. In his analysis of hominin sociality, Gamble combines Quiatt and Reynolds’ (1993) extension of release from proximity with Leroi-Gourhan’s *le geste et la parole* analytic. Within this framework, he sees the emergence of symbolically mediated material culture as the indicator of the social organization and inherent tension seen within modern sociality (Table **5**).



Ego-based network	*Principal resource*	*Size*	*Sample descriptors of modal size*
Intimate	Emotional affect	3–7	Support clique Significant others Nuclear family
Effective	Material exchange	10–23	Sympathy group Colleagues and friends Minimum band, local group, clan
Extended	Symbolic 'positive style'	100–400	Friends of friends Dialect tribe, connubium, maximum band
Global	Symbolic 'negative style'	2500	Non-significant 'Others' Linguistic family

Table 5. Social groupings proposed under the *Ego-based Network* model. Copied from Gamble 2008, 32 table 1.1.

Gamble further argues (1999) that Rodseth et al.'s social acts in absentia are a product of Upper Palaeolithic social evolution best observed within the Europe record with the emergence of the Early Aurignacian. To this same end, he argues that the Chatelperronian represents a social system that had the capacity to incorporate and manipulate new gestures but that these gestures were still framed within a set of limited Mousterian-like proximal relationships. Therefore, the utilization of symbolic material items (ornaments) by Chatelperronian Neanderthals, denotes a capacity for complex behaviour, but unlike the Aurignacian, these social actions (gestures) were performed within the proximal space of limited and closed social networks.

The Ego model is meant to enable a methodological or heuristic approach to understand the myriad forms of social alliance within an evolutionary framework. However, kinship alliance and ego-networks are by no means mutually exclusive. Kinship or at least nuclear families are central to Gamble's ego-based model. An important point to keep in mind is that the band group of 10-23 or nominally the 'magic' 25 is not comprised of prime-age adults, meaning the human band unlike the subgroups of other fission-fusion species is mixed in its age and sex classification. This limits the level of affinal alliance within what Gamble calls the "Effective Network" (thus a classic patrilocal model of a band = senior male n=1 + spouse n=1, adult sons n=2 + spouses n=2, adolescent children n=6, total = 12).

The ethnographer Lauriston Sharp named his community analysis of Cape York Peninsula aboriginals an "ego-centred set" (2009, 159). He designated these sets as being ego-based because networks and alliances “overlapped isotypically with everyone else’s” (ibid). Trade networks, ritual networks, and technological behaviours overlapped between and within networks and therefore these systems of alliance could only be encircled at the individual level. However, Sharp explains that emically these networks are understood within kinship terms, and these kinship networks provide “the basis for moving outward from the series of individuals with which one started” (ibid, 160). However, kinship alone may not be the primary mechanism for inter-band alliance.

Alliance as a response to environmental forces:

Ambrose and Lorenz (1990) outlined a model of Palaeolithic and African Stone Age subsistence, territorial, and lithic sourcing patterns, which Ambrose has developed and modified further (1998, 2001, 2002, 2006). This model does not see inter-band networking as an inherent tendency, but rather an environmental effect. Bands are seen as autonomous units within territorial ranges that are more or less closed according to the patterning of resource densities within a given environment. In the case of environments with ‘unpredictable’ resource patterns, whether low or high-density in nature, band territories are predicted to be open, allowing for information and material exchanges between bands. It is this environmental mechanism, they argue, that enables the formulation of inter-band alliance through necessity.

Though Marlowe (2005) never appears to question the universal nature of inter-band alliances, he does discuss the fact that environmental patterns do play heavily on the organizational behaviour of hunter-gatherers. Drawing on his previous fieldwork with the Hadza, Marlowe gives a brief description of the environmental conditions that effect their communal organization. These mostly relate to the availability and spacing of waterholes, which are dependent on seasonal fluctuations in rainfall. However, as Marlowe notes, the tendency of Hadza communal organization is to fission into small bands to limit internal “bickering” (58). It is the linguistic group according to Marlowe that appears to be a more viable level of grouping rather familial units forming the backbone of band formation during fissioning. Likewise, Damas (2009) argued that in Netsilik communities the formulation of kinship ties provides the structural or discursive basis for the seasonal aggregation and dispersal of larger communities.

It is interesting then to note that Service (1962, 50) assumed that early human sociality was "that of a pre-human primate group altered and subdivided in ways directly related to reciprocal, virilocal marriage modes". Virilocality or patrilocality may in fact be a good descriptive for a majority of hunter-gatherers (or for that matter most human communities) with estimates of up to 70% of human populations practicing this kinship system (Heyer et al. 2012, 598). However, the primary difference between the cohabitation behaviours of humans compared to *Pan* is that humans tend toward uxorilocal philopatric habitation after the birth of offspring (Marlowe 2004). This implies that at least with modern hunter-gatherers the human reproductive cycle appears to necessitate some form of inter-band or at least inter-familial alliance or exchange regardless of environmental circumstances.

Troops to bands and then what?

There has been a tendency to assume that larger dialectical communities or *regional groups* arose within the human lineage as an emergent property of an increased capacity to formulate inter-band alliances. For example, Rodseth et al. (1991, 223) remark, "[a]s Tylor (1888), Levi-Strauss (1969 [1949], 1956), White (1949, 1959), and Service (1962) all recognized, a key to human social evolution may lie in how local groups were first integrated, paving the way for progressively larger and more powerful political units". Likewise, it has been argued that the social complexity of modern humans developed as a direct consequence of inter-band alliance systems (Chapais 2008; Foley and Lee 1989; Gamble 2010). Under such scenarios, the human band is seen as preeminent or basal to human social organization. This is opposed to Birdsell's *equilibrium system* and Layton and O'Hara's band model, which frame the band as a facet of a larger, extended, human community, a component of a multileveled system, and, as such, a product of community fissioning. The former argument is difficult to reconcile with the *social brain hypothesis* (SBH). If bands represent the *original* or basal state of human social organization, then humans, unlike all other higher primates, present a negative relationship to the extreme between community size and neocortical area. The fission-fusion studies approach taken by Layton and O'Hara (2010) and others can rectify this discrepancy.

Fission-fusion based arguments i.e. social extension:

Cross disciplinary studies, such as the 2011 analysis by Gamble et al., have focused on the function of fission-fusion processes within the evolution of human social and emotional complexity. Contrasting with humans, pongid social behaviour is seen as comparatively less complex: there communities are composed of a fewer number of agents, they lack ritualized social mediation, and they do not extend nearly as far social bonds in time and space. From a SBH (Dunbar 1992; 1995; Gamble et al. 2011) perspective, the distinction between human and pongid fission-fusion behaviour is crucial to the understanding of human specific, social intelligence.

Gamble et al. (2011) see the evolution of social cognition as a prime mover in the emergence of emotional and social complexity, affecting the fluidity of ancestral fission-fusion behaviour. By dividing the human clade into three definitive epochs, they argue for significant shifts in the interaction size and thus social complexity from Australopithecus to modern humans. They argue that it was only with the emergence of *H. sapiens sapiens* that a form of social cognition evolved that enabled a modern form of emotional and social complexity. The SBH (Figure **25**) plays a central role in this study due to the "lack of obvious archaeological proxies" for the community sizes of past hominin species (Gamble et al. 2011, 119).

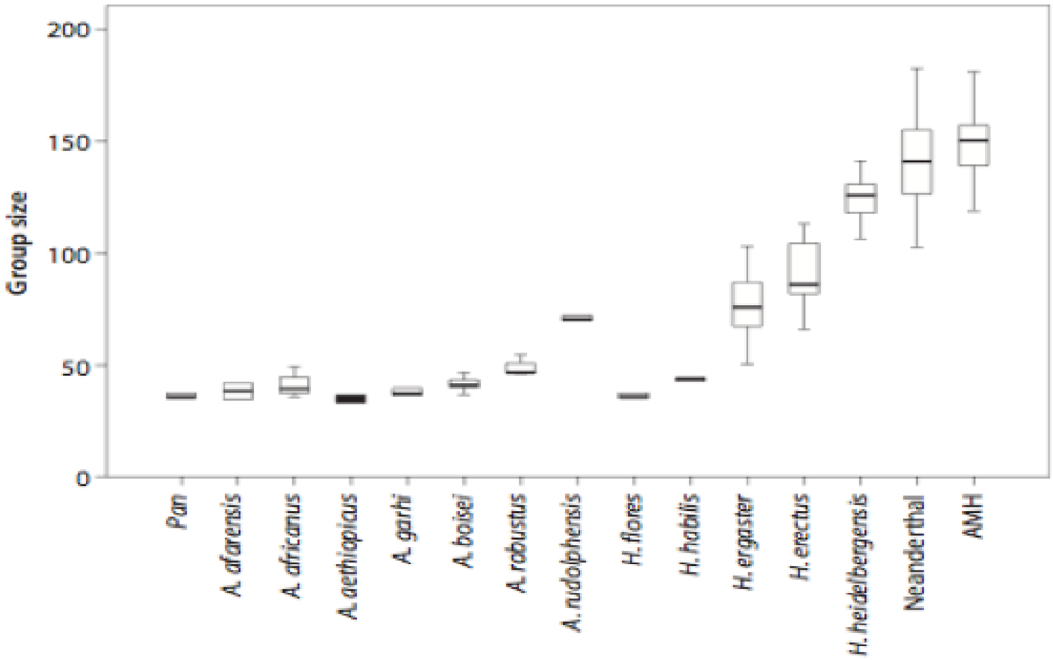
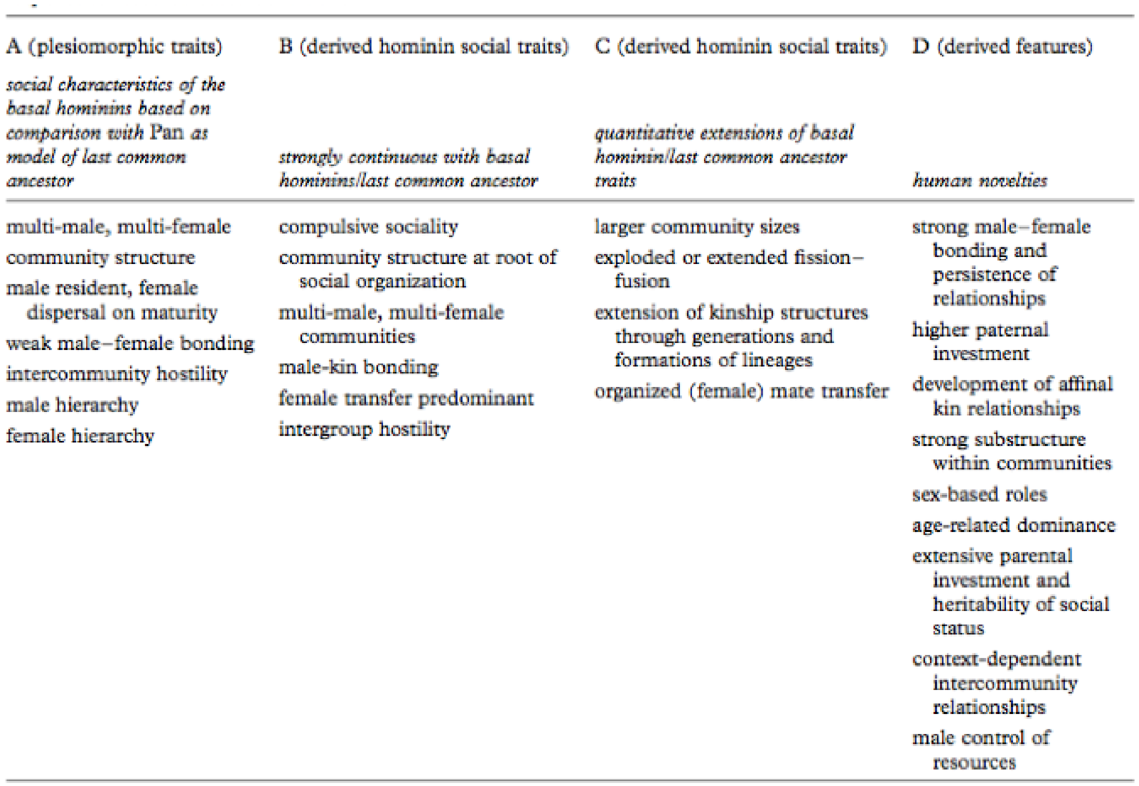


Figure 25. SBH groups size estimates from *Pan to AMH.* Copied from Gamble et al. 2011, 119 figure 2.

In an earlier paper by Foley and Gamble (2009), the evolving complexity of human fission-fusion dynamics is contextualized in a milieu of "derived human social patterns" (Table 6). The study is concerned with what is described as six crucial transitions within the human lineage: bipedalism and range size, tools and meat, fire, families and focus, social brains and technologies, and ecological intensification. Selected and selective fission-fusion processes play different roles during the six transitions according to their study.



A (plesiomorphic traits)	B (derived hominin social traits)	C (derived hominin social traits)	D (derived features)
social characteristics of the basal hominins based on comparison with Pan *as model of last common ancestor*	*strongly continuous with basal hominins/last common ancestor*	*quantitative extensions of basal hominin/last common ancestor traits*	*human novelties*
multi-male, multi-female community structure male resident, female dispersal on maturity weak male–female bonding intercommunity hostility male hierarchy female hierarchy	compulsive sociality community structure at root of social organization multi-male, multi-female communities male-kin bonding female transfer predominant intergroup hostility	larger community sizes exploded or extended fission–fusion extension of kinship structures through generations and formations of lineages organized (female) mate transfer	strong male–female bonding and persistence of relationships higher paternal investment development of affinal kin relationships strong substructure within communities sex-based roles age-related dominance extensive parental investment and heritability of social status context-dependent intercommunity relationships male control of resources

Table 6. Human social traits according to Foley and Gamble (2009). Copied from ibid, 3270 table 1.

In the first transition, the emergence of bipedalism is seen as having enabled a more effective exploitation of larger territorial sizes and capacity to meet increased foraging demand. Thus, the increased efficiency of a bipedal physiology is argued to have led to a fissioning of a previous troop sociality, reducing the total demographic base of the hominin group, a notable reverse trend in hominid social evolution (Foley and Gamble 2009, 3273). The second transition, focusing on dietary shifts toward greater degrees of carnivory is devoid of direct reference to social structural change, but as with bipedalism, the implied increase in hominin foraging ranges would have had a significant effect on subgroup and community structure. Though the third transition, effective control of fire, offered a social space around hearths, it is the fourth transition, families, that is argued to have had the greatest effect on social evolution. They suggest that this process involved an elaboration of consanguineal alliances into a nuclear structure. Foley and Gamble argue that this led to significant social change through the embedding of family units "within larger kin-based communities" (3274). It is with the fourth transition human fission-fusion dynamics are argued to have undergone an "explosion" in complexity with evidence for seasonal hunting patterns and increased raw material movement. They see these patterns as suggesting the emergence of a band organization, allowing for the extension of communities over greater distances while still maintaining the bonds of unified social units. The final transition is argued to have resulted in a reverse trend in the peripatetic nature of human communities as a result of technologically more efficient foraging practices. This combined with the emergence of plant and animal domestication enabled both sedentism and major demographic growth.

Along similar lines of logic, Grove (2012) has argued for a gradual evolution of a more flexible and dynamic fission-fusion behaviour that would have enabled successive radiations of hominin species. Each radiation is argued to have resulted in species that were increasingly more capable of adapting to and exploiting environments in higher latitudes. By contrast, Lehmann et al. (2007, 630) question such an assumption, noting that "[t]he advantage of fission–fusion… does not lie so much in colonizing new habitats…but in allowing community size to increase" (2007, 630). This is not to say that shifts in the complexity of hominin fission-fusion capacity were not important or even centrally important in the capacity to exploit fringe environments and the eventual colonisation of much of the old world. However, the need to adapt to varied, uncertain, or new ecological territories may not have been a causal mechanism in the evolution of human social complexity. Rather, the ability to exploit different and novel environments may have been a by- product of an elaboration of fission-fusion dynamics. In many ways, this reflects the inherent capacity of fission-fusion societies to extend social bonds in time and space (Gamble 1998; 1999).

The *Magic Numbers*, 25, 150, and 500

Gamble (1999) notes that there are many 'magic numbers' in anthropological and archaeological discussion of hunter-gatherer and hominin social organization: 25, 150, 500. In fact "Magic Numbers" was the title of the discussion session chaired by Binford at the Man the Hunter Symposium that sought to critically debate the evidence for universal characteristics in the social organization of hunter-gatherer communities. Ethnographic evidence of multi-level organization among hunter-gatherers is well established. Archaeological evidence is, by contrast, less clear-cut.

Ethnographic evidence:

A product of the "Magic Numbers" symposium was the recognition that Birdsell's band-level grouping of ~25 individuals was observable cross-culturally and that patterns of aggregation and dispersals (fission-fusion) were common to many different hunter-gatherer communities. Damas' description of Netsilik Inuit bands (Damas uses the descriptive *band* to mean a communal network at any size) noticed that communities were divided into extended family units averaging 15 to 20 individuals. Lee and Devore observed that fissioning is a common hallmark of conflict resolution in Mbuti society as well as that of Hadza and !Kung San, leading to a high level of individual movement between band territories within both societies (2009, 9). Turnbill (2009) observed that the fission-fusion dynamic of Mbuti communities was dependent on environmental factors, mostly the distribution of caloric resources. During midyear, or the honey season, resource abundance allowed Mbuti communities to fission into smaller bands, as cooperative hunting activities were not pertinent to exploitation during this season. The seasonal timing of aggregation and dispersal according to resource distributions allowed a "separating of antagonistic elements" that arise between agents during times of larger social aggregation (ibid, 135), which occurred within Mbuti communities during seasonal resource shortfalls.

In more recent studies, the "magic numbers" appear to be more substantive than fantastic. As discussed, Layton and O'Hara (2010) and Marlowe (2005) demonstrate that the band and *regional group* levels of organization among hunter-gatherers are common across ecological and environmental divides. Utilizing a comprehensive dataset of hunter-gatherer communities (number of cultural units = 478), Marlowe found "no correlation between local group size and primary biomass" (2005, 58), implying that band demography is not dependent on resource abundance alone. Instead, he argues that limiting factors on interpersonal alliance may affect *local group* or band size, noting that "[b]eyond 30 [individuals], conflicts between families may cause fissioning" (ibid, 59). However, he highlights that the availability and concentration of resources can result in *local group* aggregation as in the case of large

Hadza camps near permanent waterholes. Further, Grove et al. (2012, 197) note that "despite population size varying by over two orders of magnitude, and population home range by almost four orders of magnitude [between different hunter-gatherer communities], the size of the foraging group is remarkably constant, with 91% of group sizes falling between 5 and 27 and a median of 16, mean of 17, and mode of 18."

***Social brain hypothesis* (SBH):**

There are, however, empirically based assumptions that can be made about hominin community size if Pleistocene hominins followed more general social patterns observed among extant primates. The most established of these patterns is the relationship between neocortical size and group size often dubbed the *social brain hypothesis* (SBH) (Dunbar 1992, 1998; Barton and Dunbar 1997). Simply, there is a positive relationship between the total volume of the neocortex of a primate species and its group size (Figure **26**). The average size of the human brain around 1300cc implies a significantly larger group size than that of our closest living relatives, *Pan troglodytes*, with a brain size that is about 900cc smaller. The estimate for the human group size according to the established linear relationship is about 150 individuals.

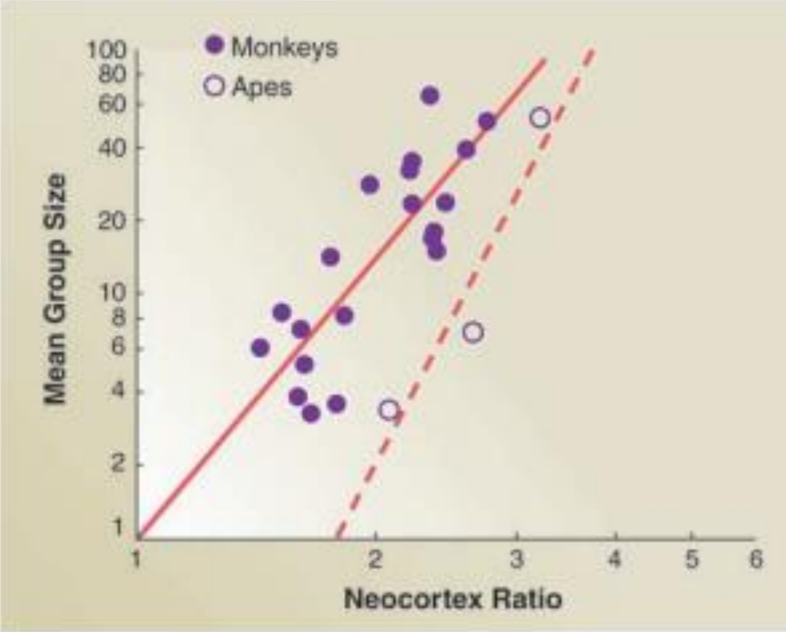


Figure 26. Relationship between neocortical size and group size among social primates. Copied from Dunbar and Shultz 2007, 1344 fig. 1.

Despite the "well-established quantitative relationship between social group size and brain…volume" (Gamble et al. 2011, 116) this demographic number may be more ethnographically elusive than one would hope. Marlowe (2005) is quite critical of the SBH estimate for modern humans, arguing that the basic human communal unit is the band, numbering around 30 agents, and that there are no ethnographic indications of a lasting hunter-gatherer communal unit that fits Dunbar's estimate of 150. He further argues against an assumption that the recent marginalization of hunter-gatherers has impacted the demographic loading of bands.

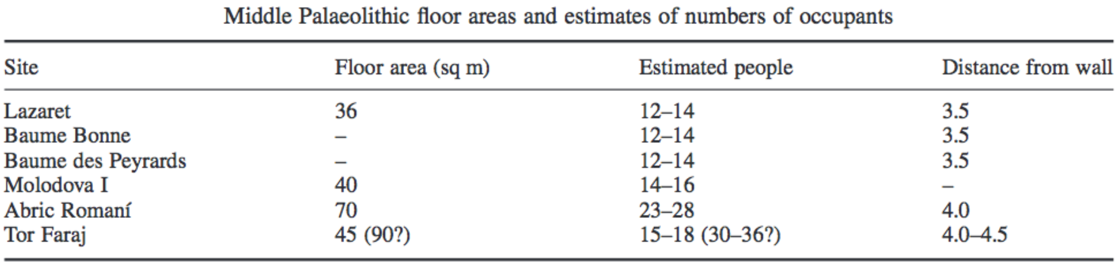
The main issue concerning the validity of the SBH does not come down to a lack of evidence for large hunter-gatherer groupings, but rather groupings that conform to the 150-agent prediction. To this end, it is the much larger linguistic group, according to Marlowe (2005), that constitutes the true size of human communities.

SBH estimates may, therefore, better represent minimum group sizes. For example, the Ngogo chimpanzee community located in the Kibale National Park, Uganda, ranges between 145 to 165 members. By contrast, the SBH predicts a community size of 60 individuals for chimpanzees (Aiello and Dunbar 1993,189 table 1). This suggests that the alliance mechanisms that are well established within the behavioural repertoire of *Pan* can result in community size nearly three times larger than the SBH estimate. As such, past human communities could have ranged from 150-450 according to a similar assumption. A community size within this range fits well with estimates for the minimum demographic size needed to maintain an endogamous network among humans (Wobst, 1974). This range is also much more reflective of known hunter-gatherer community sizes. This suggests that the positive relationship observed between group size and neocortical size among primates can be extrapolated to humans.

Archaeological evidence:

Direct archaeological evidence for band and regional group level organization is more problematic. Margaret Conkey (1980), for example, has taken a more critical view of the usefulness of theories concerning multilevel organization, or more specifically band congregations, in understanding Palaeolithic sociality. In her analysis of the social function of Altamira during the early Magdalenian, Conkey argued that systems of aggregation and dispersal are "not universal or of any great antiquity among hominid hunter-gatherers" (1980, 609). She further argued against the assumption that fission-fusion social organization equates to any kind of evolutionary threshold.

Though Conkey justifiably questioned the assumption that large sites are indicative of multi-band aggregations, this does not mean that are no proxies that can be used to estimate agent numbers. The hearth spacing analysis of the well preserved Middle Palaeolithic Level E at Abric Romaní by Vallverdú et al. (2010) suggests a spatial orientation and quantity of hearths expected from a modern mobile hunter-gatherer camp. Hayden's (2012) review of Middle Palaeolithic *living surfaces* favours the interpretation that Neanderthal social units were comparable to modern bands (Table 7).



Middle Palaeolithic floor areas and estimates of numbers of occupants

Site	Floor area (sq m)	Estimated people	Distance from wall
Lazaret	36	12–14	3.5
Baume Bonne	–	12–14	3.5
Baume des Peyrards	–	12–14	3.5
Molodova I	40	14–16	–
Abric Romaní	70	23–28	4.0
Tor Faraj	45 (90?)	15–18 (30–36?)	4.0–4.5

Table 7. Group size estimates derived from *living surface* areas. Copied from Hayden 2012, 4 table 1.

As reviewed in the previous chapter, fusion or aggregation events are rare occurrences among modern hunter-gatherers. Daily life is lived within bands, making it a sound assumption that the majority of archaeological residues from past hunter-gatherers represent activities at this level of organization. The palimpsestic nature of both open and cave sites (Bailey 2007; Bailey and Galanidou 2009) further problematizes the ability to distinguish between patterns of residues that were left by aggregations from those left by successive, smaller group occupations. It is therefore, difficult to assess the potential size of entire communities during the Palaeolithic from an archaeological perspective.

Discussion

Research into the evolution of modern human social complexity has comprised an important body of research over the past forty-eight or more years since the publication of the Man the Hunter symposium. Much of the research reviewed in this chapter pertaining to the social evolution of the *Homo* genus is highly indebted to Birdsell's formulation of hunter-gatherer sociality. Birdsell, like Layton and O'Hara

(2010), described pre-agricultural human societies as a system of overlapping multilevel organizations.

The literature reviewed in this chapter appears to argue that either ego-centred kin networks or the evolution of syntactical language enabled the formulation of multilevel societies. The works with the transition from troops to bands particularly favour ego-centred intelligence (as understood in a SBH framework) as an essential driver of human social complexity. Layton et al. (2012) rely on the SBH to understand the potential social capacities of fossil hominin species. While Gamble et al. (2011) go further and utilize SBH to assess the social cognition of individual specimens, but to the same effect of the former (i.e. assessing species-wide social capacity rather than individual capacity). The exception is Marlowe (2005) who is sceptical of the power of SBH to generate estimates for social groupings that are observable within the ethnographic record. Instead, he favours the emergence of syntactical language as key to the elaboration and complexity of the inter-band alliance systems seen among modern hunter-gatherers.

Where the *Band Model* is Different:

Though some elements of the *band model* may follow a similar argument to those seen in existing literature, Layton and O'Hara (2010) stand in contrast to many assumptions about the evolution of modern hunter-gatherer sociality. Most importantly, they do not argue for a fracturing of the human community, or a period of liminality, between the movements away from the primate troop toward the human band. Further, Layton and O'Hara take the position that continued selection for complex fission-fusion sociality underpins the evolution of behavioural modernity as opposed to the selection for complex social cognition and communication (syntactical language) enabling more complex social structures and functional organizations.

By elucidating the common fission-fusion behaviours of humans and chimpanzees, Layton and O'Hara's *band model* suggests that human sociality is an elaboration of the fission-fusion dynamic of Hominidae rather than a wholly novel system. This is to say that the functioning of a *band sociality*, as structured by ecological conditions, implies the presence of concomitant social behaviours such as syntactical language, complex agent tracking, in time and space, and a high level of interpersonal intentionality. To this effect, the social mechanisms that humans utilize require a "social setting within which [these] skills can flourish" (Carrithers 2010, 53).

Conclusion

This chapter discussed some of the existing literature about the process and possible selective pressures that led to the evolution of human social organization. Layton and O'Hara's *band model* has been shown to have much in common with Birdsell's equilibrium systems approach. Further, the review of some of the literature and ideas concerning this process has a particular bias toward either ego centred or language centred explanations for the emergence of modern hunter-gatherer sociality.

Clearly, both socially intelligent individuals and language would have played a significant role in the emergence of multilevel social organizations. From a band model perspective, human social intelligence is a product of communities that were submerged in the long-lived memories of relationships and relatedness, producing social roles, which are concomitants of this dynamic interplay. The fact that the size of hunter-gatherer communities (*regional groups*) is not dependent on ecological variables (Marlowe 2005; Layton and O'Hara 2010; Layton et al. 2012) suggests that there was a continued need for extended social alliance beyond the level of the agent or ego-based kin network. In this way, individuals in the past would have found themselves embedded in a myriad of social obligations that he or she does not hold mastery over or "possessive individualism" (Carrithers 2010, 47). This is not to say that self-interest has had no part in the story of human evolution, but that the capacity for reciprocity both in social and material resources and the need to act "pacifically toward both close kin and others" (ibid, 48) played an equal part.

CHAPTER 6

Theoretical background part II: the use of lithic technology and sourcing as a means to understand settlement patterns and territoriality

Introduction

The previous chapter explored archaeological and anthropological research to contextualize the *band model* and human fission-fusion behaviour within past and contemporary research. In this chapter, I discuss further theoretical issues concerning the analysis of territorial areas and demography as well as the relationship between these and technological *complexity*. In this thesis, I rely on "[s]ite-to-source distances for stone raw material" (Tryon and Faith 2013, 244) to interpret territorial patterns during the Middle and Upper Palaeolithic. There are a few theoretical considerations that must be addressed concerning the mechanisms that underwrote material sourcing as well as the assumptions concerning differences in the function of material sourcing between the Middle and Upper Palaeolithic. These issues deserve special consideration both theoretically and methodologically and are broken into discussions of processes of material sourcing, technological adaptation to environment, hunter-gatherer territorial areas, estimating past territorial areas from site to source information, and site to source categories as a quantifiable property.

Sourcing: exchange, direct and embedded systems

Theoretical concerns of how and why lithic materials were transferred around prehistoric landscapes have shaped the development of various methods that attempt to better understand past social and economic realities (Kelly 1983; 1992; Carr 1994; Odell 1994; Gamble 1998; 1999; Binford 2001; Burke 2006; Whallon 2006; Fernandes et al. 2008; Layton et al. 2012; Preston 2013). The analysis of *site catchment areas, conveyance zones, foraging areas, and social networks* during the Stone Age all rely partially if not heavily on assessing the distance between lithic materials recovered at sites to their geological origin.

Andrefsky (2009, 71) notes that the root of such research lies in Binford's *curation* concept (1973; 1979). Binford observed that Nunamiut toolkits were "carefully…transport[ed]" between localities to fulfil the "anticipated performance of different activities" (1973, 242). *Curation* in this case had to do with both the preparation and transport of lithic tools as well as their technological organization. Under the *curation* concept, lithic materials are procured either directly or as part of an embedded process. Direct procurement involves visits to raw material sources solely for the propose of acquiring tool stone while embedded procurement involves the accessing of lithic material within the context of daily social and foraging activities (Duke and Steele 2010, 813). The direct versus embedded dichotomy suggests different uses of the landscape.

Expanding on his observations of Nunamiut technological organization, Binford (1979, 255) argued that lithic transfers should been understood as an effect of "site functions within a settlement system". This led to the application of the *curation* concept to Binford's (1980) forager/collector model (Figure 27). Under this formulation, retouch was utilized as an indicator of different settlement patterns. High frequencies of retouch were taken to imply tool curation and a mobile forager settlement pattern while low frequencies of retouch were assumed to suggest a collector, more sedentary, pattern (Andrefsky 2009, 71).

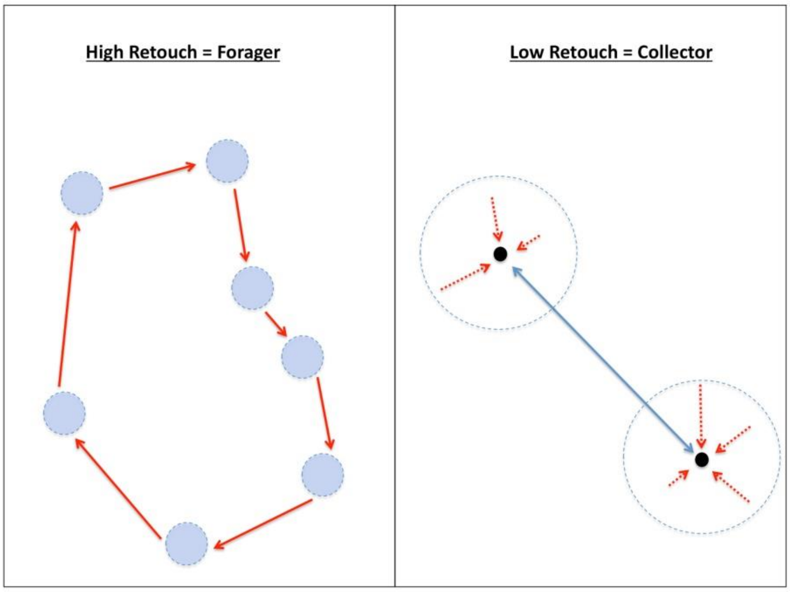


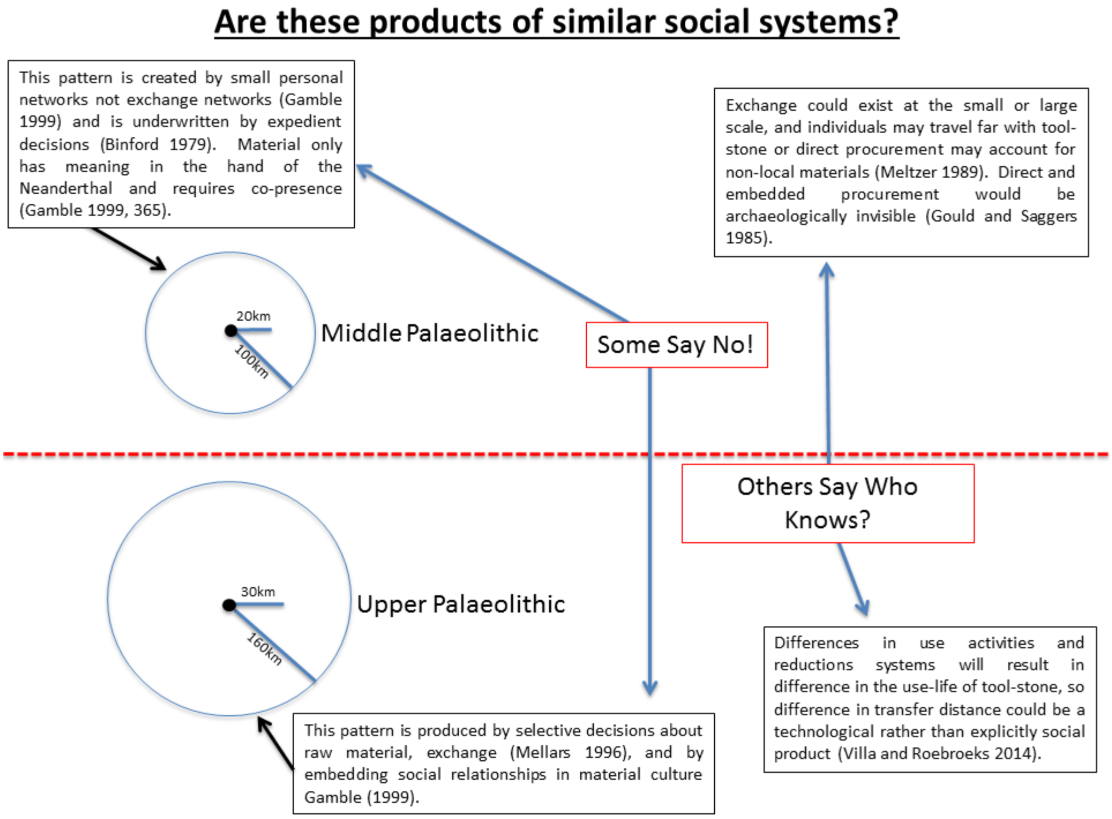
Figure 27. Forager vs. collector diagram: blue circles, foraging areas, solid red arrows, movement of retouched, curated tools; dashed blue circles, collector subsistence areas; black dots, semi-sedentary *villages*; solid blue arrows, seasonal movement between *villages*; dashed red arrows, movement of early reduction stage lithic materials and nodules. Forager/collector diagram after Rowley-Conwy (2001, 41 fig. 3.1).

Rather than simply relying on retouch indices as an indicator, Geneste (1985; 1988; 1991) examined evidence for curation within the Middle Palaeolithic record by assessing the lithological source locations of materials recovered from Mousterian sites in the Dordogne. Geneste's study involved a very detailed analysis of the relationship between source distance and the reduction stage of lithic products. This enabled him to create a model accounting for the types of lithic materials that were transferred or curated according to a specific set of categories: nodules, cores, blanks, and retouched tools. To a large degree, this model conformed to the *curation* paradigm with highly retouched tools typically corresponding to longer site-to-source distances. Féblot-Augustins (1993; 1997; 1999; 2008; 2009) continued this approach by examining changes in sourcing patterns or material transport distances (MTDs) from Middle and Upper Palaeolithic assemblages across Europe.

Gamble (1998; 1999), relying heavily on the works of Geneste and Féblot-Augustins, analysed the movement of lithic materials during the Middle and Upper Palaeolithic as products of 'taskscapes' and social landscapes. The *taskscape* is the space over which social and subsistence activities take place. Like Binford, he envisions the procurement of lithic materials happening within the context of embedded systems. Gamble argues that the Middle Palaeolithic record suggests that Neanderthals were capable of structuring their reduction strategies according to source-to-site transfer distance. Within the *taskscape*, he even sees Neanderthals making use of levallois chaîne opératoire as a form of social performance.

However, like Binford (1973), Gamble (1998; 1999) does not see Middle Palaeolithic sourcing patterns as suggestive of long-term forward planning nor processes of extended networking through exchange. He argues that lithic material transfers during the Middle Palaeolithic conform to a uniform drop off curve. This is taken to assume that Neanderthal raw material procurement was embedded in general subsistence activities rather than extended social networks. Gamble suggests that the presence of lithic material beyond the range of 20km indicates that Neanderthals carried "their environments with them" (1999, 356). Further, because site-to-source distances during the Middle Palaeolithic fall largely within 5 to 20km, Gamble argues that the longevity of Neanderthal social interactions "last[ed] about one or two days, the time needed to travel" these distances (ibid, 353).

Gamble (1998; 1999) and Binford (1973) are not alone in the assumption that Neanderthal spatial patterns imply a limited social and adaptive capacity. Several other works (Freeman 1966; Mellars 1996; Gamble and Steele 1999; Pearce et al. 2013) have concluded that Neanderthal social territories were not comparable to those of modern humans. Overall these studies suggest that Neanderthal sourcing, subsistence and technological patterns were less strategically planned and opportunistic.



Are these products of similar social systems?

This pattern is created by small personal networks not exchange networks (Gamble 1999) and is underwritten by expedient decisions (Binford 1979). Material only has meaning in the hand of the Neanderthal and requires co-presence (Gamble 1999, 365).

Exchange could exist at the small or large scale, and individuals may travel far with tool-stone or direct procurement may account for non-local materials (Meltzer 1989). Direct and embedded procurement would be archaeologically invisible (Gould and Saggers 1985).

Differences in use activities and reductions systems will result in difference in the use-life of tool-stone, so difference in transfer distance could be a technological rather than explicitly social product (Villa and Roebroeks 2014).

This pattern is produced by selective decisions about raw material, exchange (Mellars 1996), and by embedding social relationships in material culture Gamble (1999).

Figure 28. Debate over the mechanisms that caused differences between Middle and Upper Palaeolithic sourcing patterns.

However, this is a debated issue (Figure 28). For example, Villa and Roebroeks (2014) say that the reason for the more *local* characteristic of Middle Palaeolithic material sourcing could be a product of reduction processes/technological organization. Similarly, Hayden (2012) argues that this pattern could be the product of different economic realities or technological shifts during the Upper Palaeolithic such as sleds that would have enabled the transport of higher quantities of items over greater distances.

Others have argued that there is no way to differentiate embedded, direct and purely exchange-based systems (Meltzer 1989). Gould and Saggers' (1985) study of Aboriginal lithic sourcing led them to conclude that direct and embedded procurement would be archaeologically indistinguishable. Subsequent research has attempted to overcome these obstacles (Brantingham 2003; 2006; Duke and Steele 2010), but these questions still pose major analytical as well as interpretive problems. Nonetheless, Binford's (1973) assessment that Middle Palaeolithic systems do not correspond with those of extant hunter-gatherers is not explained by these critiques. The fact that Upper Palaeolithic reduction systems may be suitable to transport (i.e. *curation*) demonstrates a modern capacity for flexible adaptation. Whereas Middle Palaeolithic systems represent a non-modern behavioural repertoire, which is incapable, as the argument goes, of adjusting technological systems to meet specific environmental demands.

Environmental Forcing and Technological Intensification

The assumed *non-modern* nature of Neanderthal technical systems comes from studies that failed to detect environmentally specific characteristics. For example, Freeman's analysis of Mousterian facies led him to conclude that their geographical spread was greater than hunter-gatherer cultural areas and therefore could not be treated as cultural markers while at the same time their generalized nature could not be taken to assume that they were toolkits "specifically adapted to any environment" (1966, 235). This has produced a layering of disparaging assessments of Neanderthal capacities:

- Middle Palaeolithic toolkits and reduction processes do not conform to anticipated environmental risks (Binford 1973)
- the Mousterian does not reflect anticipated mobile strategies and planned *curation* (Binford ibid; 1979)
- the lack of technological diversity and symbolic material culture reflects small population numbers (Hovers and Belfer 2006)
- Lithic sourcing during the Middle Palaeolithic suggests small effective networks (Gamble 1998; 1999; Gamble and Steele 1999).

There are some problems, however, with these assessments from an ethnographic and ethnohistoric perspective. Firstly, comprehensive analyses of recent hunter-gatherers indicate that environmental risk does not produce the kinds of predicted technological outcomes assumed under the traditional Binfordian approach (Collard et al. 2011). Secondly, mobility does not account for the complexity of toolkits (Read 2008). And thirdly, population size or demography does not appear to predict the complexity of material culture or toolkits, as a component of the former (Collard et al. 2013).

High latitude and technological intensification:

It has been generally assumed that latitude can be utilized as a predictor of the complexity of hunter-gatherer settlement, mobility, and technology (Binford 2001). This is because a presumed increase of environmental risk in northern latitudes produces a greater complexity in forward planning and technological investment among hunter-gatherer communities (Oswalt 1976). This is most clearly stated by Torrence (2001, 79-80) who argues that the inverse relationship between latitude and species diversity leads to technological complexity through the manufacture of "special-purpose tools" that reduce the chance of failure, and thereby increase capture rates. Looking at Torrence's dataset (ibid, 76 table 4.1), this process is reflected in the number of tool-types and technical components within a given toolkit (Table **8**). It is argued that Middle Palaeolithic assemblages do not reflect the anticipated level of complexity expected from hunter-gatherers living at similar high latitudes (Kuhn and Stiner 2001; 2006; Wynn and Coolidge 2008). However, the assumption that environmental risk dictates technological intensification may not be as easily generalized under the variable of latitude as one might hope.

Ethnic Group	**Latitude**	**Instruments**	**Instrument Components**	**All Technical Units**
Tiwi	12	9	12	14
Andamanese	12	8	39	51
Ingura	14	9	22	32
Chenchu	16	14	39	55
Naron	19	7	24	40
Aranda	24	8	28	42
Owens Valley Paiute	37	13	53	107
Tasmanian	42	16	6	15
Surprise Valley Paiute	42	6	42	97
Klamath+	43	16	53	151
Twana*	48	16	77	237
Tlingit*	58	12	32	121
Tanaina*	60	23	96	224
Ingalik+	62	19	78	296
Nabesna	63	9	37	105
Caribou	63	13	51	118

Table continued

Angmakssalik*	66	22	169	202
Iglulik*	69	23	150	225
Copper	70	12	27	58
Taremiut*	71	19	136	205

Table 8. Dataset of various technical systems according to ethnic group and latitude. * marine system, + aquatic system. Data from Torrence (2001, 76 table 4.1).

Looking simply at the *instruments* (foraging and hunting tools) category, which might by more archaeologically detectible, there is clearly a positive correspondence with the quantity of tool types and latitude (Figure **29**). The same is also true for the total number of *instrument components* (the number of units or pieces that make up the instruments). At this level of resolutions, the argument that latitude = risk = technological complexity appears salient.

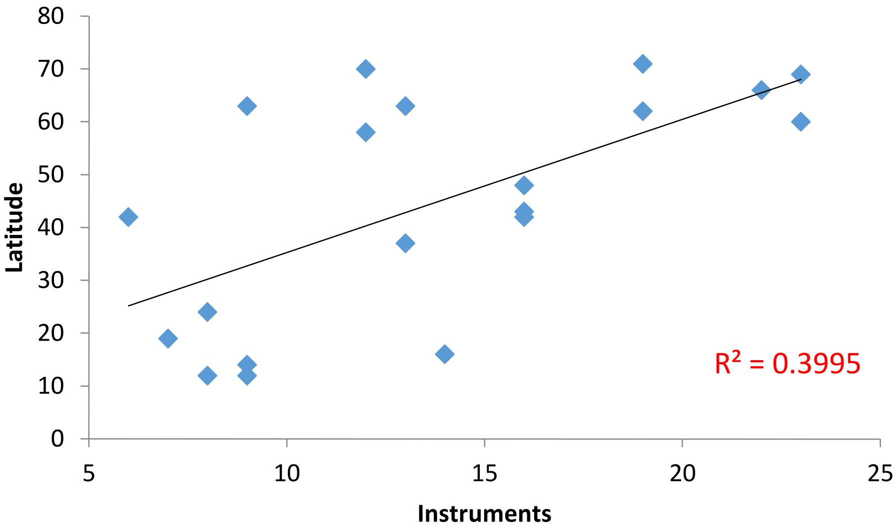


Figure 29. Number of instruments compared to latitude for the entire sample population from table 1.

There is, however, a major problem with this argument. With any correlation, there is always the possibility that other causal processes are responsible for a detected relationship other than the variables that are accounted for in a regression model. Ecology alone may in fact account for the positive correspondence. Accordingly, northern marine environments (above 48°) appear to highly bias the sample population.

The removal of toolkits directed at the exploitation of high latitude marine environments results in the loss of statistical significance ($p = 0.11$) between latitude and the number *instruments* (Figure **30**). Removing higher latitude hunter-gatherer toolkits directed at the exploitation of aquatic, lacustrine, riverine and coastal, environments reduces the significance value even further (p = 0.27).

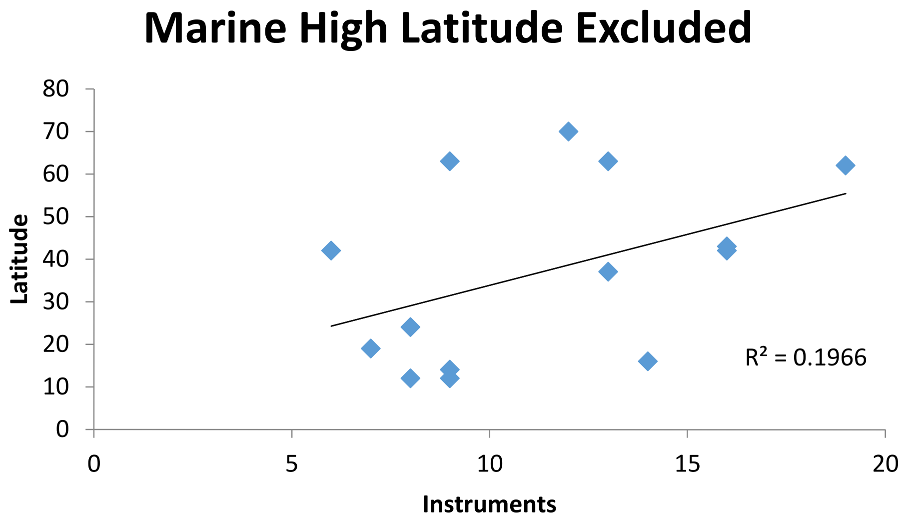


Figure 30. Number of instruments compared to latitude from table 1 minus toolkits directed at north marine environments.

The same effect is replicable at the *instrument components* level as well. The removal of high latitude marine industries results in the loss of any relevant correlation (p = 0.12) while the removal of all high latitude aquatic toolkits results in further loss of significance (p = 0.33). This suggests that even concerning the number of technical components, increases in latitude do not result in technological intensification of terrestrially based toolkits. It should be noted that without the removal of any of the samples, there is no significant relationship between the number of tool components (instrument components/instruments) and latitude (p = 0.06). This suggest that the *complexity* of any one tool-type is not well predicted by a simple variable such as 'latitude.' However, when *facilities*, hunting blinds, drives, traps, etc., are included (*all technical units* category), the correlation (though not strong) between latitude and the complexity of subsistence systems cannot be rejected (p = 0.03). This, again, may be the result of other factors than latitude alone.

In fact, the relationship between latitude and total number of components (instruments and facilities) seems overwhelmingly biased by higher latitude North American subsistence strategies, which account for 12 out of the total 13 technocomplexes above 42 degrees latitude in the dataset. What is surprising is that there is no relationship (p = 0.51) between latitude and subsistence complexity, as measured in the total number of technical units within the North American sample despite having a latitudinal range from 37 to 71. This is also true for all of the non-American samples despite a latitudinal range from 12 to 42 degrees (p = 0.57). Therefore, the relationship between the total number of components that comprise a subsistence regime and latitude appears to be an effect of significant differences between the North America sample population compared to the rest of the dataset or *vice versa*. Nevertheless, it appears that marine adaptive systems account for the impression of greater *complexity* within the North American samples (Table **9**).

Ethnic Group	**Technical Units**	**River/Lake System**	**Marine System**
Owens Valley Paiute	107		
Surprise Valley Paiute	97		
Klamath	151	X	
Twana	237	X	X
Tlingit	121	X	X
Tanaina	224	X	X
Ingalik	296	X	
Nabesna	105		
Caribou	118		
Angmakssalik	202		X
Iglulik	225		X
Copper	58		
Taremiut	208		X

Table 9. Table showing technical units and marine or aquatic association of the high latitude North American samples from Torrence (2001, 76 table 4.1).

Northern coastal environments, then, are associated with increased toolkit *complexity*. In fact, all of the 'aquatic,' fresh and salt water, North American systems are directed at the exploitation of anadromous salmonids, marine mammals, or both. Contrary to the assumption that risk is the primary driver of technological complexity, coastal environments have been re-interpreted as lower risk areas within northern latitudes (Collard et al 2011). I would argue that technological intensification is probably an effect of subsistence strategies directed at high resource density and highly patterned ecologies; in this case, the high caloric packages north coastal zones provide. Therefore, the intensification of technology could be a result of a simple cost and return process, meaning that high investment is adaptive in conditions with the potential for high rates of return.

The brief review of the relationship between generalized environmental information and technological complexity questions the long held assumption about where and when technological intensification should be anticipated. On further review, generic assumptions about technological intensification cannot preclude the possibility that Middle Palaeolithic technology falls within the range of anticipated response expected from modern hunter-gatherers. This is further supported by studies that indicate that Middle Palaeolithic reduction systems were just as economic as those of the Upper Palaeolithic (Eren et al. 2008), that tool standardization between the two periods was comparable (Marks et al. 2001), and that there was no increase in the number of tool-types from the final Mousterian to the Aurignacian (Grayson and Cole 1998). Nonetheless, this still leaves open the idea that subsistence and social areas during the Middle Palaeolithic were more restricted than those of extant hunter-gatherers. This begs the question of what is known about modern hunter-gatherer territorial areas and whether Middle or Upper Palaeolithic sourcing patterns conform to such expectations.

Ethnographic Evidence: hunter-gatherer territories

Rather than compare Middle Palaeolithic patterns to the Upper Palaeolithic, it would be more appropriate to determine whether either period suggests population densities that would fall within the range of modern hunter-gatherer variability. As noted in the previous chapter, one of the things that hunter-gatherers share in common is that they live at very low population densities, often substantially lower than other primates. Layton and O'Hara (2010) argue that this is most likely an effect of human subsistence regimes that regardless of environmental context are highly directed at the acquisition of calories from hunted prey. This means that modern hunter-gatherer population densities and band territorial areas are more similar to those of other social carnivores rather than other primates. Beyond meat consumption, the human diet is primarily dependent on glucose and starch rich flora, which also occur at low natural environmental densities. The unequal distribution of these resources in different ecologies results in a substantial difference in territorial areas of different hunter-gatherer communities (Table 10). However, this does not result in a significant difference in the number of individuals that compose bands on an annual basis nor in the number of individuals in *regional groups* (Marlowe 2005; Layton and O'Hara 2010; Layton et al. 2012).

Ecology	**Ethnic Group**	**Per./km²**	**Band Diameter**	**Regional Group Diameter**
Tropical Forest	Ache	0.03	33	146
	Aka	0.109	17	76
	Batek De	0.11	17	76
	Cholanaickan	0.6	7	33
	Mbuti	0.185	13	59
	Nukak	0.034	31	137
	Average	*0.178*	*13*	*60*
Tropical Coast	Gidjingali	0.46	8	37
	Gunwinggu	0.05	25	113
	Tiwi	0.4	9	40
	Yolngu	0.34	10	43
	Average	*0.313*	*10*	*45*
Savanna	Hadza	0.34	10	43
	Yolngu	0.06	23	103
	Average	*0.2*	*13*	*56*
Semi-desert	G/wi	0.07	21	95
	Ju/'hoansi	0.017	43	194
	Warlpiri	0.01	56	252
	Western Desert (Australia)	0.015	46	206
	Average	*0.028*	*34*	*151*
Temperate Coast	Kwakiutl	0.405	9	40
	Nootka	0.4	9	40
	Tlingit	0.715	7	30
	Average	*0.507*	*8*	*35*
Boreal Forest	Cree	0.004	89	399
	Khanti	0.005	80	357
	Average	*0.005*	*84*	*376*
Arctic Coast	Central Canadian Inuit	0.009	61	274
	Hudson Bay	0.016	45	199
	Netsilik	0.005	80	357

Table continued

	Taremiut	0.1	18	80
	Average	*0.032*	*31*	*140*
Arctic Interior	Nunamiut	0.02	40	178

Table 10. Ethnographic synthesis showing populations densities by ecological association. Data from Layton and O'Hara (2010, 86-7 table 5.1). Band and *regional* group diameters calculated using a heuristic model from Whallon (2006) and Layton et al. (2012), which is further explained in this chapter.

There is a high degree of difference in population density among modern hunter-gatherers, ranging from 0.6 to 0.004 persons per km2. This results in a global average of 0.173 persons per km^2. As noted by Layton and O'Hara (2010), what defines modern human social capacity is not the ability to maintain large effect network sizes *per se*, but the ability to extenuate and maintain these networks over large temporal and spatial distances. Comparing the hunter-gatherer average to our closest living relatives, *Pan troglodytes* (2.5/km^2), shows that hunter-gatherers maintain communities over a space fourteen times larger. Even the highest hunter-gatherer population density (0.6/km^2) suggests a territory over four times that of pongids.

If Neanderthal and Upper Palaeolithic AMH sociality was similar to extant hunter-gatherers, then site to source distance during the Middle and Upper Palaeolithic should suggest territorial ranges that would result in population densities somewhere between 0.6 to 0.004 persons per km^2. If material transfers during either period suggests a population density that falls near or below the global average (0.173 p/km^2), this may suggest a sociality system that is capable of flexibly responding to different ecological circumstances.

Determining whether site-to-source distances reflect the anticipated population densities requires a means to model this information. Whallon (2006) and Layton et al. (2012) provide a heuristic approach that models material transport distances (MTDs) within a *band model* framework. The following section explains this model and applies it to Middle and Upper Palaeolithic sourcing patterns according to Féblot-Augustins (1999).

Assessing territories from MTDs

Layton et al. (2012) and Whallon (2006) use similar models to reconstruct past hunter-gatherer territorial areas. This approach relies on the use of maximum material transfer distances within a given region or time period to determine the extent of a *regional group* territorial area as well as provide general estimates of population density (Figure **31**).

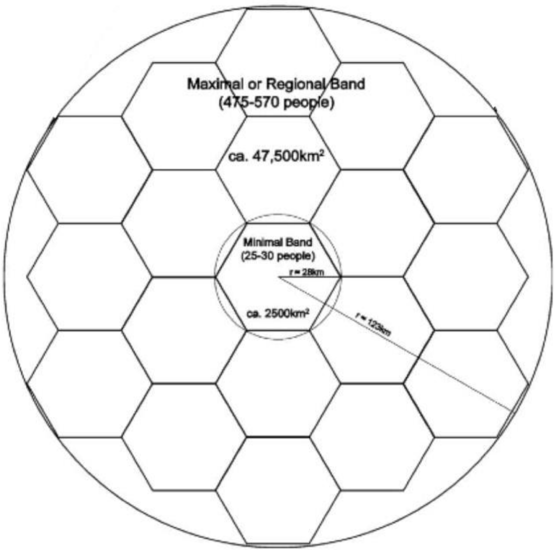


Figure 31. Heuristic model used to estimate prehistoric hunter-gatherer territorial areas and populations densities modified from Whallon (2006, 267 fig. 4).

This approach uses a simplified method, relying on transfer distances as radius or diameter. Therefore, it envisions band and *regional group* territories as circles, which does have its limitations, as discussed more fully in the discussion section of this thesis. However, this heuristic method is best utilized as an initial method to contextualize MTDs within known hunter-gatherer territorial parameters. Maximum transfer distances are treated as proxies for maximal community sizes averaging ~500 individuals. This can be used to estimate band territorial areas, which account for the majority of transfer distances within a given time or region. For example, using the information from Figure **31**, the population density should be ~0.01 persons per km^2 (Table **11**).

Maximum Transfer Distance = 246 km (*123 km radius*)

Estimated *Regional Group* Area	**Estimated Band Area**	**Estimated Population density**
47,500 km^2	2,500 km^2	0.01 p/km^2

Table 11. Territorial and demographic estimates derived from previous figure.

This approach can be used to test whether Middle or Upper Palaeolithic territories conform to expectations drawn from modern hunter-gatherers.

Modelling Middle and Upper Palaeolithic MTDs:

To model territorial areas during the Middle and Upper Palaeolithic, I rely on the recording of maximum transfer distances from Féblot-Augustins (1999) as a proxy for the diameter of *regional groups*. I do not use the absolute maximum distances record for either period, but instead, I use distance categories that account for less than ten recorded occurrences from either period. During the Western European Middle Palaeolithic (MIS3), this equates to 100 km (ibid, 229 fig. 1), and 160 km (ibid, 238 fig. 11) for the Upper Palaeolithic. I utilize these categories as proxies for movements across *regional groups* rather than band territories due their low frequency occurrence. For example, Féblot-Augustins notes that there are only 38 known occurrences of lithic transfers beyond 100 km from the very beginning of the Chatelperronian to the beginning of the Magdalenian (2006, 451). Since very large aggregations are rare among modern hunter-gatherers, I would expect for archaeological traces of such processes to be equally rare and limited. I also use these distance categories as diameters rather than radii to avoid biasing toward low population density estimates, which might over-suggest parity with the modern hunter-gatherer synthesis.

Period	**Regional Group 500 individuals Territory**	**Band 25 individuals Territory (km^2)**	**Band Territory Diameter**	**Population Density**
Middle Palaeolithic	7,854 km^2	393 km^2	22.36 km	0.064 p/km^2
Upper Palaeolithic	20,106 km^2	1,005 km^2	35.78 km	0.025 p/km^2

Table 12. Middle and Upper Palaeolithic territorial and population density estimates. MTD data from Féblot-Augustins (1999).

If these estimates are accepted (Table 12), then maximum sourcing distance during the Middle Palaeolithic implies a population density of 0.06 agents per km^2. The Upper Palaeolithic implies a population density of 0.024 agents per km^2. These indicate that population densities during both periods fell well within the known spectrum of hunter-gatherer territorial areas. Both also fall significantly lower than the global hunter-gatherer average, which may imply that Neanderthals and AMHs shared a very flexible band sociality. Even though this is a simple model, it does appear to have relevant predictive power.

Using only the long distance transfer categories, band territorial diameters can be predicted (table 5). This equates to ~22 km for the Middle Palaeolithic and ~36 km for the Upper Palaeolithic. I would therefore predict that the vast majority of lithic transfers should fall within these respective distances. This appears in fact to be the case. Mellars (1996, 165) notes that in the Upper Palaeolithic material transfers beyond 30km increase and transfers up to 30 km can account for 20% of site assemblages whereas the majority of Middle Palaeolithic sites present a transfer pattern largely confined within 20 km. Herein lies the problem with assuming that *local* equates to non-modern. It is true that Middle Palaeolithic sourcing patterns are on average more local relative to the Upper Palaeolithic, but this does not mean that Neanderthal social networks and territorial areas were necessarily different from those of modern hunter-gatherers. This begs the question of how exactly material transfer distances have been examined as discrete and quantifiable categories.

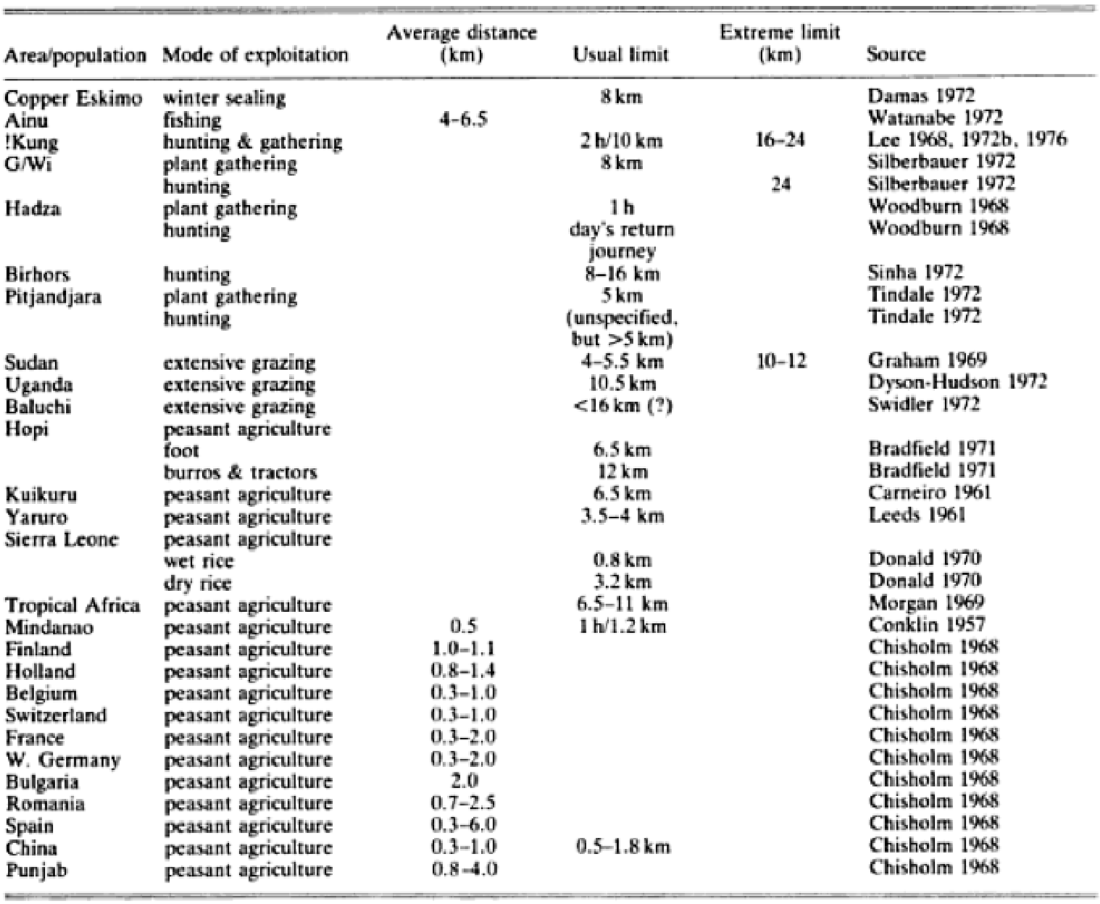
What is local?

It has been argued that evidence for large community and network sizes are scant prior to the Upper Palaeolithic. This largely comes down to the observation that Lower and Middle Palaeolithic tool stone site-to-source distances "indicate a predominantly local pattern with very little being transported beyond 20 km (Gamble 1999, 124 citing Féblot-Augustins 1990; 1997). However, 20 km does not necessarily indicate a limited interaction area. Many *community* landscapes are formulated within such distances (Table 13).

Archaeological/Ethnographic Example	Radius	Notes
South African MSA sourcing area	20km	Walker 2014
Howieson's Poort sourcing area	20km	ibid
Cantabrian UP sourcing area	20km	ibid
Mesolithic N. Britain sourcing area	20km	Donahue and Lovis 2006
Okla mound political boundary	20km	Blitz 1999
Yanomamö village territory	20km	Fix 1975
Semai village territory	20km	Fix 1975

Table 13. Common interaction/option zones within a 20 km radius.

Designating something as 'local' in archaeological literature can mean many different things depending on period and region. For example, the designation of *exotic* can often be used to suggest non-local origin. Simply, exotic material can be a lithic type that has good conchoidal fracturing properties and occurs at low frequency within a given archaeological sequence. The lack of clarity in the relationship between materials designated as 'exotic' and their source distance has led to debate, as an example, in South African MSA research (Ambrose 2006; 2010; Minichillo 2006). The traditional divisions of 'local,' 0-5km, 'semi-local,' 5-20, and 'non-local' or 'long-distance,' >20km, follows Geneste's (1985; 1988) work on Middle Palaeolithic sourcing patterns in southwestern France. This does appear to be a valid framework, as daily subsistence activities are noted often to occur within a 0-5km radius of centralized occupation sites (Table **14**).



Area/population	Mode of exploitation	Average distance (km)	Usual limit	Extreme limit (km)	Source
Copper Eskimo	winter sealing		8 km		Damas 1972
Ainu	fishing	4-6.5			Watanabe 1972
!Kung	hunting & gathering		2 h/10 km	16–24	Lee 1968, 1972b, 1976
G/Wi	plant gathering		8 km		Silberbauer 1972
	hunting			24	Silberbauer 1972
Hadza	plant gathering		1 h		Woodburn 1968
	hunting		day's return journey		Woodburn 1968
Birhors	hunting		8–16 km		Sinha 1972
Pitjandjara	plant gathering		5 km		Tindale 1972
	hunting		(unspecified, but >5 km)		Tindale 1972
Sudan	extensive grazing		4–5.5 km	10–12	Graham 1969
Uganda	extensive grazing		10.5 km		Dyson-Hudson 1972
Baluchi	extensive grazing		<16 km (?)		Swidler 1972
Hopi	peasant agriculture				
	foot		6.5 km		Bradfield 1971
	burros & tractors		12 km		Bradfield 1971
Kuikuru	peasant agriculture		6.5 km		Carneiro 1961
Yaruro	peasant agriculture		3.5–4 km		Leeds 1961
Sierra Leone	peasant agriculture				
	wet rice		0.8 km		Donald 1970
	dry rice		3.2 km		Donald 1970
Tropical Africa	peasant agriculture		6.5–11 km		Morgan 1969
Mindanao	peasant agriculture	0.5	1 h/1.2 km		Conklin 1957
Finland	peasant agriculture	1.0–1.1			Chisholm 1968
Holland	peasant agriculture	0.8–1.4			Chisholm 1968
Belgium	peasant agriculture	0.3–1.0			Chisholm 1968
Switzerland	peasant agriculture	0.3–1.0			Chisholm 1968
France	peasant agriculture	0.3–2.0			Chisholm 1968
W. Germany	peasant agriculture	0.3–2.0			Chisholm 1968
Bulgaria	peasant agriculture	2.0			Chisholm 1968
Romania	peasant agriculture	0.7–2.5			Chisholm 1968
Spain	peasant agriculture	0.3–6.0			Chisholm 1968
China	peasant agriculture	0.3–1.0	0.5–1.8 km		Chisholm 1968
Punjab	peasant agriculture	0.8–4.0			Chisholm 1968

Table 14. Typical subsistence areas from Jarman et al. (1982, 30 table 7).

Being clear in what 'local' means is important both methodologically and theoretically. First, the validity of comparative studies is dependent on whether materials being examined have been subject to the same quantitative process. Second, it has often been assumed that more local sourcing patterns imply a less complex and less socially demanding behavioural system. This is particularly true in studies that have compared lithic transfer distances between the Middle and Upper Palaeolithic. The data on lithic material sourcing used in this thesis have all been quantified under Geneste's framework. Therefore, I use the description of *local* to mean materials sourced within 0-5km distance.

Discussion

The Middle and Upper Palaeolithic records differ in their general technological characteristics and material sourcing patterns. This has led to the conclusion that Neanderthals and AMHs differed in their social and technological capacities. For example, some have argued that the foraging behaviour of Neanderthals and AMHs were not comparable and that this suggests significant differences in the social organization of the two species (Kuhn and Stiner 2006; Márin-Arroyo 2013).

Kuhn and Stiner (2006) argue that the archaeological record associated with Neanderthals lacks evidence for a wide diet breadth, small game hunting, and specialized processing tools. They infer from this that Neanderthal subsistence behaviour lacked a gender division of labour. This mostly follows from research arguing that Neanderthals were large game specialist with a very narrow diet breadth (Richards et al. 2000; Richards and Trinkaus 2009; Buck and Stringer 2013). However, recent research refutes these assumptions, demonstrating that Middle Palaeolithic subsistence strategies included a widespread use of floral resources (Hardy et al. 2009; Henry et al. 2011; Hardy et al. 2012; Sistiaga et al. 2014), fishing (Hardy and Moncel 2011, Hardy et al. 2013, Bocherens et al. 2014, van Neer and Wouters 2010), and small game exploitation (Blasco et al. 2014; Gabucio et al. 2014). With further evidence for specialized hide working tools (Soressi et al. 2013), it appears that evidence for a gender division of labour among Neanderthals is comparable with that for Upper Palaeolithic.

The examination of technological complexity and material sourcing in this chapter suggests that the way in which Middle and Upper Palaeolithic records differed may not have been very significant. However, processes by which materials were sourced during the Middle and Upper Palaeolithic have not been addressed in this chapter thus far.

Invariably the sourcing, transport, and life history of selected raw material must firstly be dependent on their initial intention for selection. Secondary factors such as recycling and exchange make the terms "sourcing," "provisioning," and "curation" problematic (Shott 1996; Odell 1996; Nash 1996). These terms are often framed within dichotomous relationships that may not necessarily have been part of the processes that resulted in the archaeological record such as *expediency* and *curation* (Binford 1973; 1979) or *personal network* and *extended network* (Gamble 1999). As Shott (1996, 268) notes, the acceptance of many of these frameworks has produced internal inconsistencies. For example, the assumption that Middle Palaeolithic sourcing systems do not reflect an engagement with long term planning in as much as they were not intended for *curation.* Insistently then, intensive retouch and source dependent discard are also considered diagnostic characteristics of some facies of the Middle Palaeolithic such as the Quina Mousterian.

This study does not attempt to resolve the issue of how lithic materials were transferred during the Palaeolithic. Lithic sourcing distance, however, is assumed to reflect the area over which social behaviours did take place and thus are our best indication for the territoriality of past *communities* or social units.

Under the *band model*, both exchange as well as the movement of persons should be anticipated. As Goodyear notes, exchange between bands were nonetheless the "by-product of movement" (1979, 9). Therefore, whether by exchange or direct procurement, transfers of raw materials are proscribed within territories dependent on the carrying capacity of the surrounding landscape. Because both Middle and Upper Palaeolithic transfer distances fall within a range expected for modern hunter-gatherers, I assume that, as with modern hunter-gatherers, exchange as well as the movement of individuals resulted in the transfer of material during the Palaeolithic. It is for this reason that I try to use the term *interaction areas* were possible in this thesis. This is opposed to exchange or procurement zones.

Conclusion

This chapter has explored issues relating to the use of technological and material sourcing patterns to understand settlement and territorial patterns during the Palaeolithic. The critique provided in this chapter concerning technical complexity during the Middle Palaeolithic cautions against *posteriori* inferences that Neanderthal subsistence behaviours differed from modern expectations. More importantly, the examination of synthesized sourcing patterns (Féblot-Augustins 1999) during the Middle and Upper Palaeolithic, implies that both Neanderthal and early AMH social territories were comparable to those of extant hunter-gatherers. Though this seems highly suggestive that Neanderthals and AMHs practiced a similar fission-fusion system, the inference would be stronger if it could be determined that both demes had similar group sizes. Even if this condition were met, it could still be suggested that Neanderthal and AMH differed in their dynamic flexibility (Grove et al. 2012). Given the general diversity of hunter-gatherer fission-fusion behaviour, it is important to test whether Neanderthals and AMHs responded in kind to changes in ecological circumstances. Addressing this question is of central importance to this thesis.

The following chapter outlines the methods and approaches used to adapt the *band model* to archaeological investigation. These include both statistical and heuristic approaches to understand Neanderthal and AMH social behaviour during the Middle and Upper Palaeolithic.

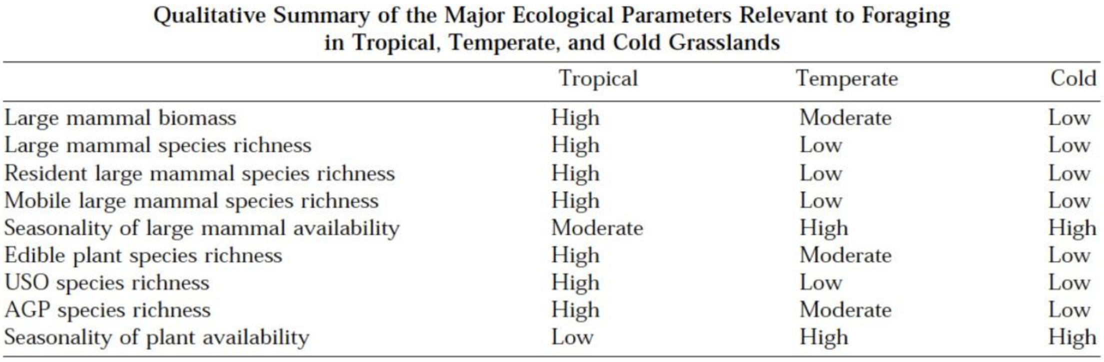
CHAPTER 7

Methods: syntheses, heuristic and statistical approaches, and predictive models

Introduction

This chapter provides an outline of the methods used to examine Neanderthal and AMH sociality, and thereby adapt the *band model* to archaeological investigation. Data syntheses, heuristic and statistical methods and predictive models are discussed and outlined in detail.

Band sociality is an outcome of a deeply rooted fission-fusion behaviour shared by humans and chimpanzees and many other gregarious species. Total size of Hunter-gatherer communities, *regional groups*, are much larger than that of chimpanzee troops. Greater elaboration of fission-fusion dynamism among humans compared to chimpanzees suggests that community size affects the complexity of fission-fusion behaviour. Territory is dependent on subsistence regimes as an effect of ecological conditions. Depending on ecological circumstance, there can be significant differences between hunter-gatherer territorial sizes and demography. Large aggregations are rare, but contacts between bands will always be maintained even if ecological conditions do not allow for large aggregations. Kelly (2003, 51-2) notes that, regardless of how large the territorial extent of individual communities, the locations of individuals in the landscape are often familiar to other community members. In ecologies that support high levels of patterned and abundant resources, hunter-gatherers are afforded the ability to congregate into larger local groups/bands.



Qualitative Summary of the Major Ecological Parameters Relevant to Foraging in Tropical, Temperate, and Cold Grasslands

	Tropical	Temperate	Cold
Large mammal biomass	High	Moderate	Low
Large mammal species richness	High	Low	Low
Resident large mammal species richness	High	Low	Low
Mobile large mammal species richness	High	Low	Low
Seasonality of large mammal availability	Moderate	High	High
Edible plant species richness	High	Moderate	Low
USO species richness	High	Low	Low
AGP species richness	High	Moderate	Low
Seasonality of plant availability	Low	High	High

Table 15. Resource patterns of tropical, temperate, and cold environments. From Marean (1997, 199 table 4).

Because increasing rates of carnivory appear to have played a central role in reducing human population densities compared to other primates, I assume that the socioecology of prey would have been a strong selective mechanism that shaped fission-fusion behaviour and territoriality during the Palaeolithic. In the temperate to cold environments of Western Europe from MIS4-2, calories derived from faunal resources may have been more significant than from flora (Table **15**). Further, faunal assemblages are the most readily available proxy for subsistence practices during the Palaeolithic. I therefore use faunal assemblages, contextualized within reconstructions of site level and regional environments, to interpret ecological shifts that would have impacted human fission-fusion dynamics and by extrapolation demography and territorial sizes. To this end, I have synthesized multiple factors that account for the density and patterning of prey species commonly associated with the Middle and Upper Palaeolithic archaeological record of Western Europe. These species include cervids, such as red deer and reindeer, bovids, equids, and caprines. The faunal synthesis aids in the heuristic reconstruction of fission-fusion behaviour as well as quantitative analyses.

With the faunal synthesis providing significant ecological information, I examine changes in source to site lithic transfer distances as an indicator of interaction areas and band territory sizes during the Middle and Upper Palaeolithic. This involves an analysis of the relationship between faunal and sourcing patterns of nine assemblages from four archaeological sites, spanning the Mousterian to the Magdalenian. I expand this analysis to model demographic and sourcing patterns from MIS4 to MIS2 under the assumption that the fission-fusion behaviour described by Layton and O'Hara's *band model* (2010) underwrote both Neanderthal and AMH sociality.

The following sections outline the methods utilized to achieve these analyses. Palaeoenvironmental and technocomplexes information from MIS4 to MIS2 are provided in a general synthesis; a faunal synthesis is discussed; a heuristic model is outlined and discussed; methods used for examining community sizes of the LCA of Neanderthals and AMHs are outlined; the approach used to test the relationship between faunal and sourcing patterns in the archaeological record is detailed; and, the construction of material sourcing and demographic models are explained.

Syntheses

Environmental, palaeoclimatic, cultural, and faunal data are used to construct two general syntheses used in this thesis. The first synthesis concerns general environmental, palaeoclimatic and cultural information. This synthesis enables a macro-level contextualization of the survey areas and provides a comparative framework for the analysis of individual site horizons. The second synthesis summarizes socioecological information on extant species that most closely relate to the species that compose the faunal assemblages examined.

Cultural and environmental Synthesis:

To contextualize the site level analyses within the general lithic cultural trends and environmental patterns of the latter Middle Palaeolithic and Upper Palaeolithic, a synthesis of pertinent information has been compiled that spans MIS4 to the end of MIS2. Cultural and related faunal assemblage data has been adapted from Discamps (2014), Jaubert et al. (2011), and Grayson and Delpech (2003). Palynological data that concern regional floral trends was taken from Riehl et al. (2014) and Fletcher et al. (2010). J. Guiot generously provided seasonal temperature estimates from his analysis of the Grande Pile Pleistocene, lacustrine deposits (Guiot et al. 1992; Guiot 1990). The palynological data and temperature estimates were aligned with the NGRIP interstadial curve as adjusted by Sánchez Goñi et al. (2008). This data is compiled into one diagram (Figure 32) to enable a clear representation of the chronological relationship of this information.

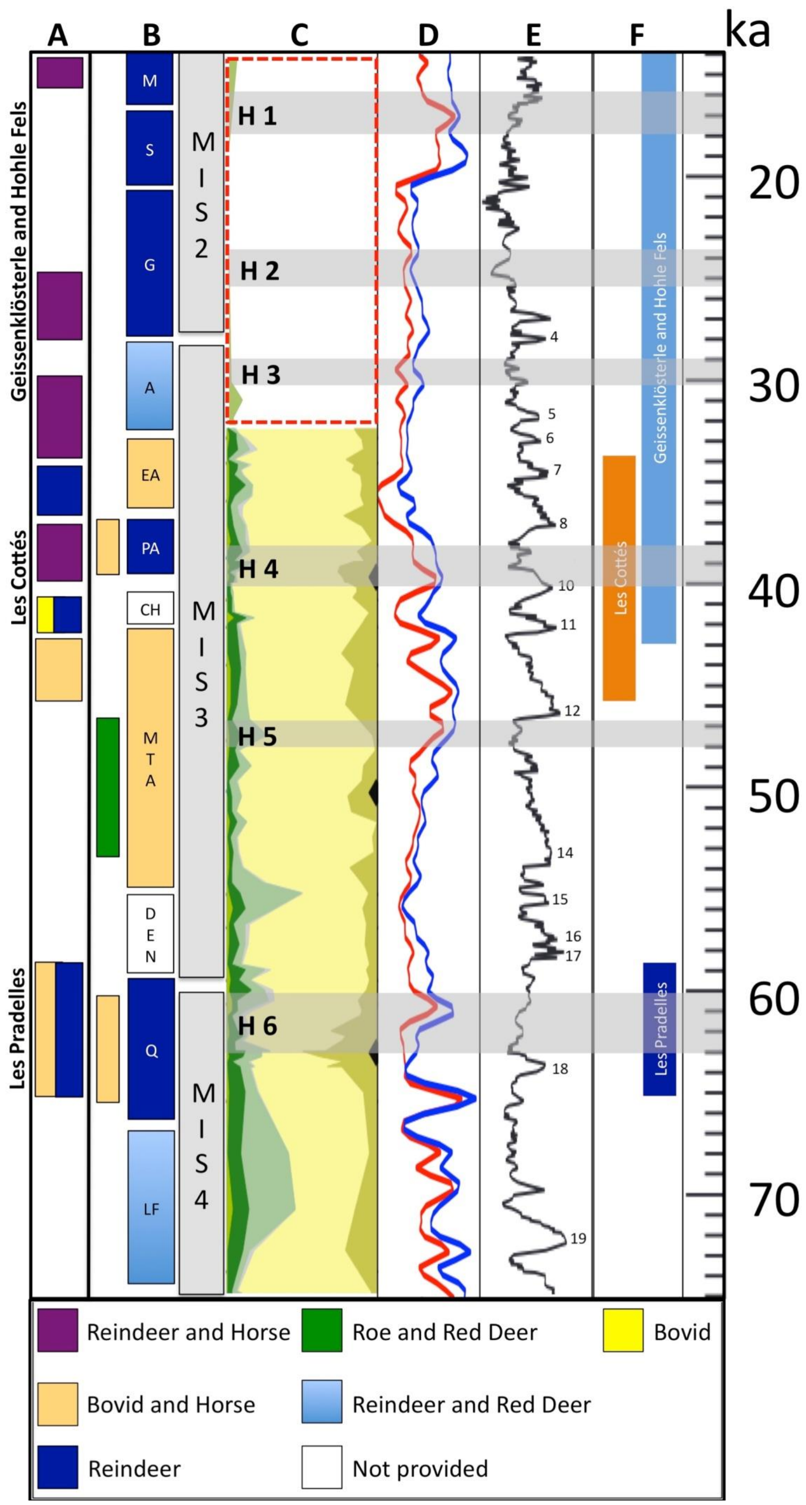


Figure 32. Environmental and cultural synthesis. A. Dominant fauna from each level used in regression model. B. General synthesis of faunal association per industry (Mousterian to Aurignacian) from Discamps 2014, 3 fig. 1 and (Gravettian to Magdalenian) Grayson and Delpech 2003: M = Magdalenian, S = Solutrean, G = Gravettian, A = Aurignacian, EA = Early Aurignacian, PA = Protoaurignacian, Ch = Chatelperronian, MTA, DEN = Denticulate Mousterian, Q = Quina, LF = Ferrassie Charentian sub-phase. C. Pollen diagrams, tree pollens in green and grass pollens in olive, upper diagram (in red box) from Riehl et al. 2014 fig. 5, showing *Pinus* from botanical/palynological analyses of Hohle Fels, bottom diagram from Fletcher et al. 2010, 2848 fig. 3 Calypso core MD04-2845, D. summer (red) and average (blue) temperature estimates from Grande Pile core sequence provided by Guiot, movement to the left indicates warming and to the right indicates cooling of air temperature, E. NGRIP interstadial curve from Sánchez Goñi et al. 2008, 1142 fig. 3, F. chronology of sites used in the regression and heuristic models.

In constructing this synthesis special consideration is given to changes in the pattern of prey species. Two economically important species during the Middle and Upper Palaeolithic transition were red deer and reindeer. This synthesis suggests that reindeer progressively dominate the faunal assemblages of the Upper Palaeolithic. Mellars (1973) argued that the increase of reindeer in faunal assemblages starting with the Aurignacian indicates a shift toward specialized economic behaviour. Grayson and Delpech (2002; 2003; 2005) have called this proposition into question by arguing that statistical examination fails to uphold the assumption of greater hunting specialization during the Upper Palaeolithic compared to the Middle Palaeolithic. Instead, they suggest that environmental change during MIS3 to MIS2 accounts for the nearly monospecific nature of Upper Palaeolithic faunal assemblages.

It has long been recognized that predominantly reindeer specific faunal assemblages from Aquitaine during the MP/UP transition is associated with environmental indicators of an open landscape (Gamble 1999, 208 *referencing* Bordes and Prat 1965, Delpech 1976, Dennell 1983). In a comprehensive analysis of the faunal record from Saint Césaire, Morin (2012) observes a trend toward a monospecific focus on reindeer. Like Grayson and Delpech, he argues that this trend was a product of climatologically driven environmental change. Banks et al. (2008a; 2008b) similarly argue that downward trends in seasonal temperatures during late OIS3 continuing to the LGM resulted in an ecological shift from red deer toward reindeer dominant faunal assemblages. This assumption is further supported by the fact that the two cervid species inhabit relatively exclusive ecological ranges today. The environmental processes that underwrote this trend have become better realized over the past decade.

There is little doubt to the "hard, empirical fact" that reindeer are the dominant species in faunal assemblages starting with the "earliest stages of the Aurignacian" (Mellars 2004b, 615). However, monospecific reindeer assemblages are not uncommon from the previous glacial cycle, MIS 4 (Figure **33**). Roe and red deer are predominant in assemblages prior to Heinrich event 5 (H5), indicating a "closed deciduous woodland vegetation" (Stewart 2004, 181). During MIS 3, there was a shift from red deer dominant assemblages toward increasing exploitation of equids and bovids (Discamps 2014; Jaubert et al. 2011). As the environment became more cold and arid, the landscape became increasingly more open, leading to a shift in cervid species from red deer to reindeer. This is supported by the Calypso core (MD04-2845), which shows an increase in grass pollens to the detriment of tree pollens from MIS 3 to MIS2 (Fletcher et al. 2010).

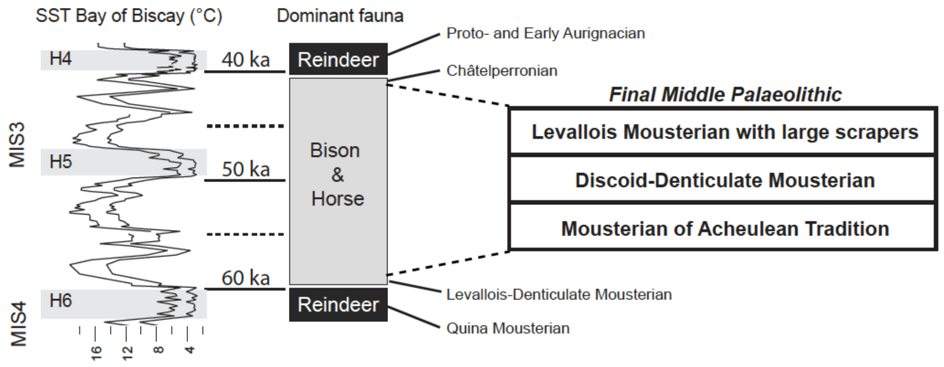


Figure 33. Faunal synthesis for the Middle/Upper Palaeolithic transition in the SW France (Jaubert et al. 2011, fig. 2).

Overall the environmental and ecological contexts of the Middle Palaeolithic (MIS4-3) and Upper Palaeolithic (MIS3-2) were non-correspondent. Given this, if Neanderthals and Upper Palaeolithic AMHs shared a *band* sociality, I would assume that territorial areas and population densities were different between the two periods. In order to fully examine this potential, careful consideration needs to be given to the chrono-stratigraphic circumstances of each site examined to enable an appropriate alignment of site-level environmental information with the synthesis.

Faunal synthesis:

The dominant species from the assemblages analysed in this thesis are reindeer, red deer, ibex/chamois, bison, and horse. Despite being an economically important species between H6 and H5, only small fragments of roe deer were noted from the sterile and earliest Aurignacian levels at Geissenklösterle while none have been recorded at Les Cottés and Les Pradelles. Many of these species have a fission-fusion social structure: reindeer (Body et al. 2014), red deer (Albon et al. 1992), roe deer (Pays et al. 2012), bison (Fortin et al. 2009), and some equids (wild asses and zebra (Kaczensky et al. 2011; Sundaresan et al. 2007), but not Przewalski's Horses (Kaczensky et al. 2011). All of these species present a gendered behaviour with males typically being more solitary and having home and annual ranges that are larger than those of females. Information on annual ranges, grouping sizes, physical characteristics and daily movements were synthesized for the dominant species (Table **16**). This information is discussed for each species in the following sections.

Species	Annual Range km^2 (a)	Annual Range Diameter	Typical grouping (b)	Pop/dens km^2 (c)	Body Mass (d)	Mass/km^2	kcal/km^2 (e)	Daily Movement (g)	Sources
R. tarandus	442000	750.18	92	2.9	95	275.5	281010	9	a. Messier et al. 1988; b. Calef et al. 1976, 207 table 1; c. Thomas et al. 2003, 73 table 6; d. Nowak 1999, 1129; e. Krasnokutsky 1996, 41; f. White and Trudell 1980, 522 table 7; g. Gunn et al. 2013, 17 table 5
R. tarandus (forest/boreal)	1000	35.68	23	2.91	160	465.78	475093.33	1.1	a. Thomas et al. 2003, 72 table 5); b. Nagy et al 2004, 11; c. Thomas et al., 73 table 6; d. ibid 2003, 18; e. Krasnokutsky 1996, 41; f. estimated from tundra reindeer relative to body size; g. Rettie and Messier 2001, 1937 table 5
C. elaphus	45	7.57	38.5	6	309	1854	1891080	1.1	a. McCorquodale et al. 1989; b. McCorquodale et al. 1989, Innes 2011; c. Jedrzejewska et al. 1997; d. Innes 2011; e. same as reindeer; f. Christianson and Creel 2009, 606; g. Kamler et al. 2007, 115 table 1
Bos	300	19.54	20	2	500	1000	2040000	3	a. Daleszczyk et al. 2007, 269, Wilson and Zittlau 2004, 12 (estimate based on 3 home ranges per annum); b. Pucek et al. 2004, 29; c. average as reported Nowak 1999, 1162 ; d. Krasnokutsky 1996, 41; e. ibid; f. Pucek et al. 2004, 27; g. Nowak 1999, 1162
Equus	471	24.49	3.25	3.8	278.93	1059.93	1271914.29	3.5	a. Kaczensky et al. 2008, 1766; b. Kaczensky et al. 2008, 1767; c. Vernes et al. 2009; d. Kuntz et al. 2006, 4563 table 3 average; e. Krasnokutsky 1996, 41; f. Kuntz et al. 2006, 4560; g. Kaczensky et al. 2008, 1765
R. rupicapra/C. ibex	1.86	1.54	17.5	5.7	42.5	242.25	259449.75	0	a. Grignolio et al. 2004, Fankhauser and Enggist 2004, 292-3); b. Nowak 1999, 1213 & 1223; c. Framarin 1985, 51; d. Nowak 1999, 1213 & 1223; e. USDA report (goat, game meat); calculated as (body mass * 0.02); g. N/A

Table 16. Faunal synthesis of the dominant prey species.

-R. tarandus

Reindeer are by far the most mobile and dynamic fission-fusion species within the associated faunal assemblages. Nonetheless, there are very significant differences between tundra and boreal reindeer. Reindeer that inhabit the tundra are medium to large bodied, typically weighing about 95kg (Nowak 1999, 1129). The distance they move in one day can exceed 50km during migrations (ibid). However, this is on the extreme end of seasonal mobility. Boertje (1985, 37 table 4) has indicated an average daily movement of 11.5km, but this was derived from estimated rather than tracked movements. A nine-year study that tracked barren-ground caribou using satellite collars recorded an average daily movement of 9km (Gunn et al. 2013, 17 table 5). This study provides the most relevant information about the daily and seasonal movements of tundra or open landscape reindeer, as it is based off direct observation rather than estimation.

Total herd sizes in the tundra can be as large as 500,000 animals, and typical groupings may range from 10-1,000 reindeer (Nowak 1999, 1129). A synthesis of aerial observations indicated a wide seasonal variability in group size, ranging from 12 to 168 reindeer with an average of 92 (Calef et al. 1976, 207 table 1). Population densities are typically around 0.7 to 3 individuals per km^2 (averaging 1.8km2) (Kumpulan et al. 2000), but during seasonal aggregations, densities can be as great as 19,000/km^2 (Nowak 1999, 1129). Daily food intake is surprisingly low, ranging between seasons from 0.86 to 2.44kg of plant matter, averaging 1.99kg (White and Trudell 1980, 522 table 7). Annual ranges are very large. One study, conducted over a twenty-year period, observed annual range sizes from 160,000 to 442,000km^2 (Messier et al. 1988). Bergman et al. (2000) suggest that the latter end of these observations is more common.

Groups of reindeer that inhabit woodland or the boreal zone often have very different annual ranges, seasonal patterns, and daily movements compared to open landscape reindeer. Boreal reindeer are typically larger than their open landscape counterparts with female sizes ranging from 110-150kg and males from 160-210kg (Thomas and Gray 2003, 18). Though they can have group sizes comparable to tundra caribou, Nagy et al. (2004, 11) observed significant seasonal change in the group sizes of caribou in Canada's North Western Territory. Some groupings were as low as 2 individuals while larger group sizes ranged from 20 to 26. Notably, boreal reindeer can be non-migratory (Callaghan et al. 2011), which accounts for their smaller annual territories compared to reindeer from the tundra. Some of the largest annual, herd ranges have been estimated at 25,000km^2 (Schaefer et al. 1999). This is twenty times smaller than the larger range sizes recorded for reindeer from the open tundra. Overall, observations of range sizes vary from less than 1,000km^2 to ~25,000km^2 with the frequency of observations peaking between 2,000 to 20,000km^2 (Thomas 2003, 72 table 5). Seasonal ranges on the other hand can be quite small. For example, during spring and summer when doe support dependent calves, ranges may be as small as 100km^2 (Rettie and Messier 2001, 1936 fig. 2). Given their smaller seasonal and annual ranges, the average distance boreal reindeer travel *per diem* is significantly shorter than tundra reindeer. A multiyear study using satellite collar tracking found average daily movements to be ~1.1km (ibid, 1937 table 5).

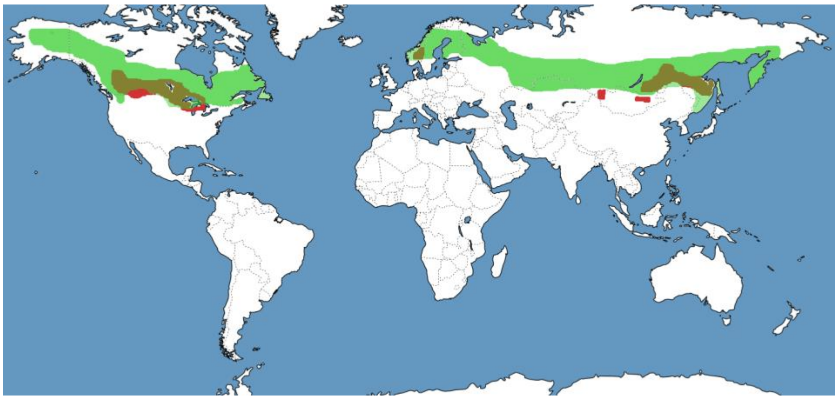


Figure 34. Map showing distribution overlap of reindeer and red deer, (red) as compared from IUCN range maps accessed 20/10/14 (http://maps.iucnredlist.org/map.html?id=41785 and http://maps.iucnredlist.org/map.html?id=29742). Green zone indicates the Taiga (boreal) ecological range redrawn from Memorial University *Halo* project webpage (http://www.mun.ca/biology/boreal/index.php).

-C. elaphus

Red deer are larger than reindeer with female size typically around 265kg and males 353kg (Innes 2011). Red deer, like reindeer, can be migratory and non-migratory. Their presence in Pleistocene assemblages has been considered indicative of an ecological context that would not be favourable to reindeer (Banks et al. 2008a). There is, however, one ecological zone in which red deer and reindeer overlap today: the central and southern portions of the boreal or taiga zone in North America, Europe, and East Asia (Figure **34**).

Like boreal reindeer, the annual ranges of red deer show a degree of variability. A study using radiocollar tracking recorded home ranges between 4.1km^2 to 30.6km^2

with females typically falling to the lower end (Catt and Staines 1987). A two-year study of red deer conducted by McCorquodale et al. (1989) in the arid environment of south, central Washington State, USA, found that female annual ranges averaged ~305km^2 and male ranges ~285km^2. However, this region is considered an arid steppe environment, which places red deer populations under a unique set of strains. This is particularly true when it is considered that red deer need to consume 153kcal/kg (Oldemeyer et al. 1993, 67), equating to ~2kg of plant matter per 100kg of body mass or 6.18kg per day on average (Christianson and Creel 2009, 606). Therefore, the Washington arid steppe example is most likely an extreme case. Even McCorquodale et al. note that the nearest annual range size in their comparative sample was only ~45km^2 (ibid, 32 fig. 2). The daily ranges of individual red deer can be quite restrictive, suggesting that individuals and small groups may only travel about 1.1 km per day (Kamler et al. 2007, 115 table 1).

Groupings vary as well and can range from 2 to 100 individuals. Large aggregations typically occur during the calving season. Studies of red deer in the American state of Montana have recorded average groupings in open landscapes of ~7 individuals while groupings in closed woodland were smaller, averaging about 3 agents (Innes 2011). Groupings in the open and arid regions of south, central Washington varied from 27 to 55 individuals (McCorquodale et al. 1989). In one controlled study, red deer populations were maintained at a maximum carry capacity density of 20/km^2 in one section of a woodland and 4/km^2 in another; population restrictions were relaxed for one year, which resulted in a reduction of population densities in both study areas to 10.8/km^2 and 6.6/km^2 respectively (Stewart et al. 2009, 306). Over a century's worth of historical and forestry management records from the Bialowieza Forest of Eastern Europe indicate red deer numbers from 0-5.4/km^2 (Jedrzejewska et al. 1997). Taken together with the controlled study, it may be safe to assume that red deer population densities should be anticipated between 5 and 11 agents per km^2.

-C ibex and R. rupicapra

Ibex and chamois both inhabit montane environments, but differ in their body sizes and social groupings. Ibex range in size from 35 to 150kg with females being typically much smaller than males (Nowak 1999, 1223). Ibex groupings are between 10 and 20 individuals though young males usually form smaller units (ibid). Chamois are overall smaller, weighing 25-50kg, but their group sizes are typically bigger at 15 to 30 agents (ibid, 1213).

Though ibex may be constantly on the move, a 2-year tracking of alpine ibex using radiocollars showed that annual movements were limited to a maximum area of 1.86km^2 (Grignolio et al. 2004). This suggests that maximum distances travelled in any direction would be restricted to about a one and half kilometre diameter for most of the year. Likewise, home ranges for chamois are considerably small; in one study, an area of only 16km^2 was observed to support 250 individuals while home ranges were observed between 1.4 to 2.4km^2 (Fankhauser and Enggist 2004, 292-3). For this reason, I have estimated the average daily movement for both species at 0km per day. This is because I am only interested in prey movement between points in the landscape rather than the total distance that prey may accrue during daily transhumance or within a pattern of concentric grazing.

Population densities have been recorded for alpine chamois and ibex communities at 7.1 and 4.3/km^2 respectively (Framarin 1985, 51). These numbers stayed constant in the study area for a 25-year period, suggesting that both species had reached population equilibrium (ibid, 53). However, these population densities may be artificially high due to a lack of predation and a cessation of hunting after WWII (ibid, 53). I have averaged these measurements (equalling 5.7 individuals per km^2) to hopefully reflect a realistic density for either species if they were under pressure from predation.

-Bos

Bison can inhabit both woodland and open grassland, but both types of bison require significantly more bio-productive environments than cervids (Discamps 2014, 4 fig. 2). Woodland North American bison are often classified as their own sub-species (*Bison bison athabascae*) and are generally larger than their grassland counterparts. Though there are differences in population density and annual range between woodland and grassland bison, these are not as marked as those between open and closed landscape reindeer. For example, home ranges for European woodland bison have been recorded between ~25km^2 to ~150km2 (Daleszczyk et al. 2007, 269) while American bison home ranges have been recorded between 27km^2 to 82km^2 (Wilson and Zittlau 2004, 12). Interestingly, Daleszczyk et al. (2007) have negatively correlated home range size with forest cover in woodland bison, suggesting that grassy areas within forests encouraged higher population densities. This may suggest that wild plains bison have slightly smaller home ranges than their woodland counterparts.

There are differences between the mobility patterns of woodland and grassland bison. Woodland bison are typically non-migratory while grassland bison do migrate (Krasnokutsky 1996, 38). Claims have been made for bison migrating up to 500km (ibid), but migrations probably fall below 300km (Wilson and Zittlau 2004, 19). There is a fair amount of variability in bison population densities. Nowak (1999, 1162) states that 0.7 individuals per km^2 is a typical population density. However, Wilson and Zittlau (2004, 12) note that woodland bison have a minimum threshold of 0.5-0.8 individuals per km^2. There is no firm determination as to the whether woodland and grassland populations live at different population densities, and both subspecies have been observed at population densities as high as $5/km^2$ (ibid, 64).

-Equus

Wild horses (*Equus ferus przewalskii*) may be one of the best proxies for assessing the behaviours of equid specimens found at Palaeolithic sites, however the ability to assess their natural behaviour is hampered by their status as a severely endangered species (Batsaikhan et al. 2006, 115-6). This is particularly true in attempts to determine population densities. Alternatively, free ranging ‘wild’ or feral horses can provide useful information on population densities. Aerial observations in Australia have recorded population densities of feral horse at 3.8 individuals per km^2 (Vernes et al. 2009). This may be a reliable estimate for the average population density of wild horse. For example, recordings in New Zealand (Linklater et al. 2000, 144) show an average density of $3.6/km^2$ with observations ranging from 0.5 to $8.9km^2$.

Groupings among Przewalski’s horses are based on age and gender. Harems (dominant male, females, dependent offspring) have been observed to average 5 individuals while groups of juvenile males ranging from 1 to 3 individuals (Kaczensky et al. 2008, 1767). Kuntz et al. (2006, 4560) recorded daily consumption by free-range Przewalski’s horses at 10kg of matter per day. Though this may suggest a prerequisite for environmental abundance, Kuntz et al. (ibid, 4557) note that the unique anatomy of the horse digestive system allows for the consumption of nutrient poor flora. Nevertheless, this may account for variability in territorial sizes, which have been recorded between

152km^2 and 826km^2 (Kaczensky et al. 2008, 1766-7). Likewise, daily travel distances can be quite long. For example, a short-term study of feral horses in the Australian outback recorded travel distances that averaged 15.9km per day for a six-day period (Hampson et al. 2010). However, a four-year study using gps tracking of Przewalski's horses produced much different results, recording average travel distance at 3.5km per day (Kaczensky et al. 2008, 1765).

Heuristic Model

The 25/500 model for hunter-gatherer societies discussed in Chapter 4 is a useful tool that accounts for the general characteristics of band societies, but it hides the variability in fission-fusion dynamics between communities living in different ecological contexts. The normal variation in fission-fusion behaviour seen today among different human communities would have had a significant effect on the Palaeolithic records of different regions and time periods. In order to address this variability, I have developed a heuristic model that accounts for some of the variance that occurs in band size and mobility as a product of fission-fusion based adaptation to specific environmental circumstances. This also allows for a discussion of potential concomitant outcomes. This heuristic approach combines the *band model* with the observations on local group variance from chapter 4 within a framework for analysing material sourcing that was developed by Ambrose and Lorenz (1990). Within this model, variances in band mobility and size are labelled *fission-fusion modalities*.

By modality, I mean a mode of hunter-gatherer sociality as an ecologically conditioned outcome. Within this framework, population densities and the sourcing distances of lithic and other materials are explicitly viewed as products of ecological and environmental conditions. I do not negate the potential that exchange networks may evolve in different directions to overcome the deleterious or limiting effects of environmental hardship as has been previously argued (Whallon 2006; Ambrose 2002; Ambrose and Lorenz 1990). Nevertheless, I assume that systems of exchange and inter-agent dependencies are important regardless of ecological circumstances, and the need to foster and maintain these relationships are paramount in hunter-gatherer societies regardless of ecological context.

It is important to re-emphasize the bipartite organization, the band and the regional group, even in cases where ecology may permit a blurring of these scales. The *regional group* comprises the maximum number of agents within a hunter-gather community. There is of course variability in the true number of agents when *regional groups* are observed in real world contexts. There is also variability in the number of agents within a band, but this is dependent on ecological conditions. By contrast, regional group variability does not seem to be dependent on ecology. Rather, variance that is recorded in the number of agents comprising a *regional group* is best understood as a fluctuation in demographic equilibrium as described by Birdsell (2009). Therefore, the physical extension of sourcing/exchange regimes in actual space does not equate to an increase in the number of agents involved in the system, but rather the space over which the community is contained as a product of environmental carrying capacity. In this regard, increases in material sourcing distances should be seen as socioecological products rather than an outcome of intensifying inter-agent networks/relationships.

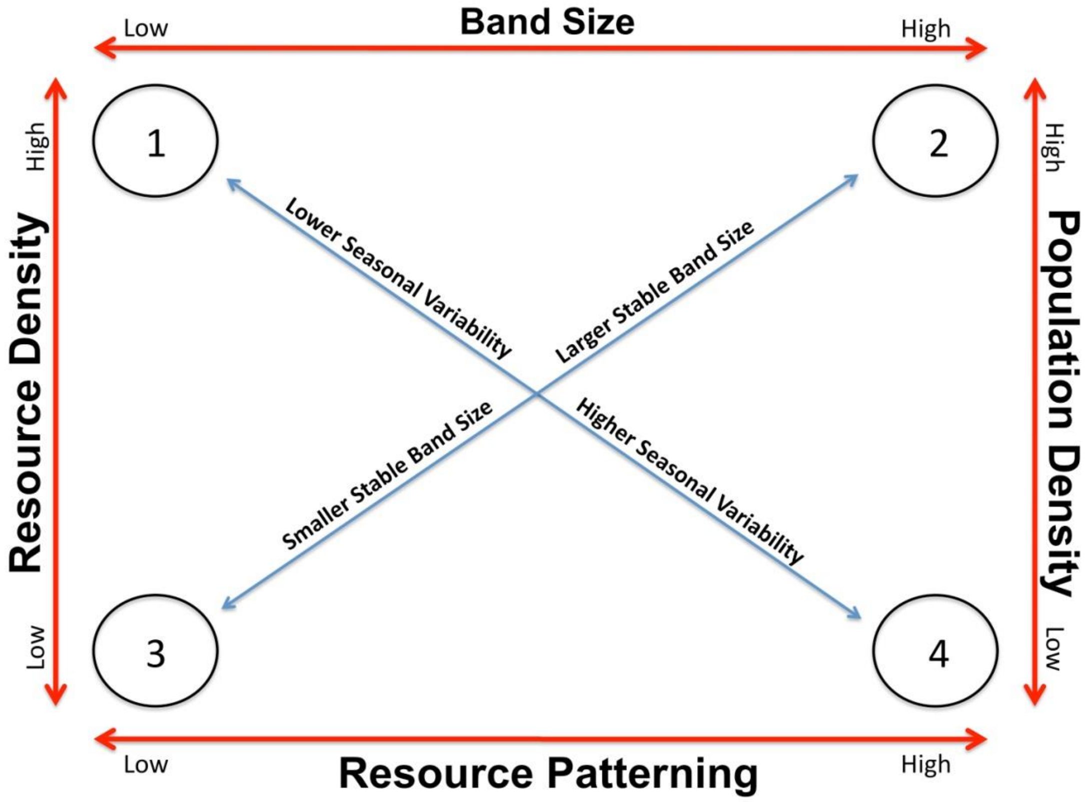


Figure 35. Heuristic model of hunter-gatherer bands within a fission-fusion framework. After Ambrose and Lorenz (1990, 9 figure1.1).

The following set of descriptions detail the four fission-fusion modalities that rest on the extreme ends of two intersecting axes, band seasonal variability and band stability (Figure **35**). The framework in which these descriptions are placed is based on Ambrose and Lorenz (1990, 10 table 1.1).

Modality 1

High Resource Density/Low Resource Patterning: raw material sourcing is local, longer home stays centred around base camps thus fewer moves between sites, small to average band size 15-35 individuals, moderately high dietary diversity, high population density. Fission-fusion dynamic: low band visits, movement between band territories conducted by individuals.

Modality 2

High Resource Density/High Resource Patterning: raw material sourcing is local with some semi-local materials, long home stays and large base camps, structured seasonal moves, high annual dietary diversity with low seasonal dietary diversity, large band size >35 individuals, dietary diversity should be high. Fission-fusion dynamic: large bands that may approach effective population size, large aggregations on a seasonal basis.

Modality 3

Low Resource Density/Low Resource Patterning: raw material mostly local with some semi-local and few non-local sources, short home stays, very mobile, dietary diversity is moderate, but may be very low at the site/camp level, small to very small band size <10-15 individuals. Fission-fusion dynamic: sharing of band territories is high, i.e. sharing of territories between bands.

Modality 4

Low Resource Density/High Resource Patterning: material sourcing is semi-local (>5km) with higher frequencies of nonlocal materials as a result of larger band territories, seasonally conditioned stays at base camps, fewer moves then under *condition 3*, but longer travel distances between moves, band size is seasonally dependent but on average large (>35) splitting into smaller groupings (10-25 individuals) for large parts of the year, dietary diversity should be low. Fission-fusion dynamic: high fission-fusion dynamism with fissioning and fusing of bands according to seasonally dependent resource availability.

I see no merit in assuming that any of these modalities could be more or less taxing on social intelligence. Modality 1 (high resource density/low patterning) does not afford large aggregations, meaning that greater pressure will be placed on individuals to maintain contacts and formulated marriage arrangements etc. Modality 2 (high density/high resource patterning) suggests that inter-personal conflict is less readily resolved by reformulation of band membership. Modality 3 (low density/low patterning) should mean that much like caloric resources the predictability of individuals in the landscape would be very low, placing pressure on bands and individuals to affectively maintain contact. Modality 4 (low density/high patterning) suggests that since environmental mechanisms would drive aggregation and diffusion, there would be a high degree of turnover in residence and co-habitation.

Applying the model:

The heuristic model is used to enable a more detailed investigation of fission-fusion patterns especially at the micro-level of the primary test site, Les Cottés, and the comparative sites, Geissenklösterle and Hohle Fels. In order to better explain the application of this model, the following discussion provides a brief, macro-level analysis of the Middle/Upper Palaeolithic transition. I approach this issue from two sets of information previously discussed, general trends in faunal data and general trends in lithic material sourcing.

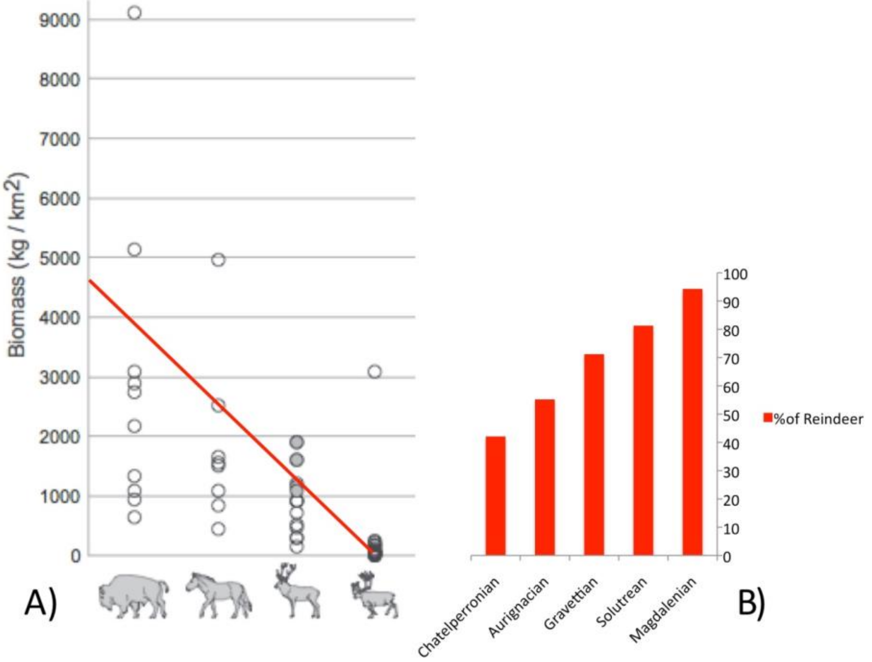


Figure 36. Biomass requirements and faunal trends during the Upper Palaeolithic. a) Modified from Discamps (2014, 4 fig. 2). b) Percentage of reindeer throughout the UP sequence of Grotte XVI; percentages from Grayson and Delpech 2003, 560 table 2.

The classic, southwestern French site of Grotte XVI records a significant increase in the exploitation of reindeer throughout the entirety of the Upper Palaeolithic sequence, reflecting a similar pattern recorded throughout the region (Grayson and Delpech 2002; 2003; 2005). Given that Middle Palaeolithic assemblages, by contrast, are primarily composed of bovid and horse (Delagnes and Rendu 2011; Discamps et al. 2011; Jaubert et al. 2011; Discamps 2014), the trend recorded at Grotte XVI (Figure **36**) is one of a progressive transition away from a Middle Palaeolithic subsistence regime. Differences in subsistence regimes should imply a comparable level of disparity in fission-fusion patterns or modes. The increase in grass pollen, the decline of arboreal pollen and the steady decrease in annual temperature during MIS3-2 (Figure 32) imply a shift from a mixed woodland and steppe toward a tundra environment. Likewise, the faunal transition from bovid and horse to reindeer during this period is most likely a product of environmental change. Under such a scenario, I would anticipate a transition in fission-fusion behaviour from modality 1 to modality 4 (Figure **38**a).

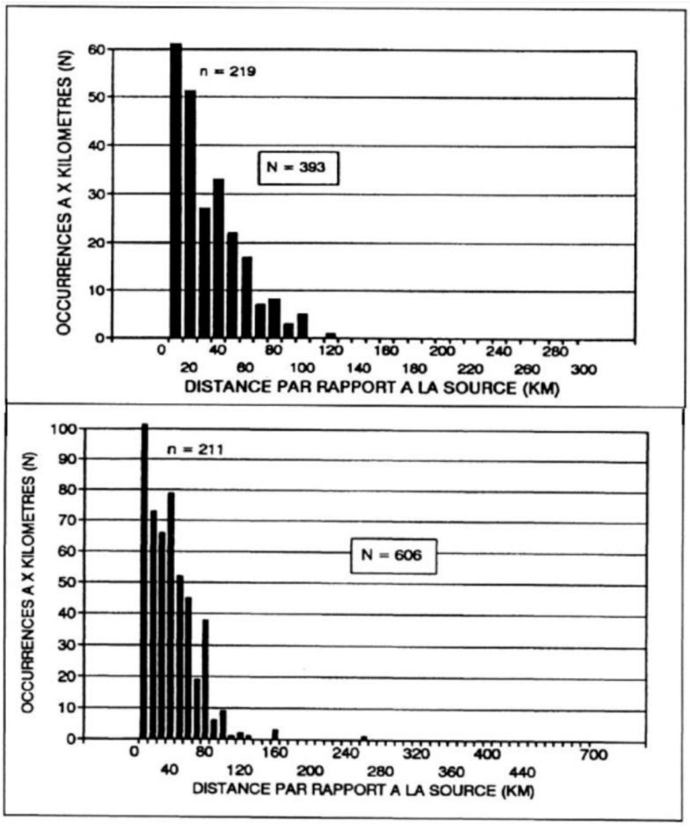


Figure 37. Lithic material transport distances for Western Europe: top MP, bottom UP. Copied from Féblot-Augustins (1999 229 fig. 1 and 238 fig. 11).

Looking at material transport distances in Western Europe during the same period (Figure **37**), it is clear that the Middle Palaeolithic is more local and more limited in its spatial scale compared to the Upper Palaeolithic. If environmental information, in the form of faunal data, matches this scenario, then the expansion in sourcing regimes during the Upper Palaeolithic would be indicative of increases in band and regional group territorial areas as an effect of decreasing carry capacity. This suggests that fission-fusion behaviours during the Middle Palaeolithic fell between modes 1 and 3 whereas the Upper Palaeolithic should predominantly fall toward mode 4 (Figure **38**b).

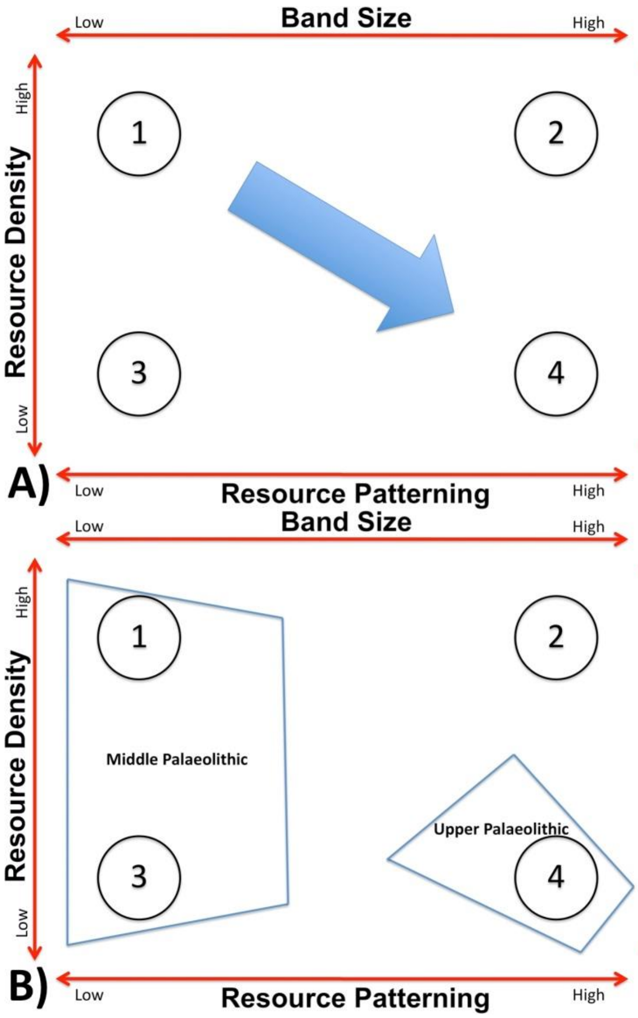


Figure 38. Model predictions: a) trend suggest at Grotte XVI according to Grayson and Delpech (2003) b) hypothesized Middle and Upper Palaeolithic patterns.

The environmental, cultural and faunal syntheses can be used as a database to test these assumptions within the heuristic framework. These show that faunal patterns were different between the Middle and Upper Palaeolithic. The patterns can be divided into five types according to industry for the Middle Palaeolithic and six for the Upper Palaeolithic (Table **17**).

Technocomplex	kcal/km²	Daily Movement
Ferrassie Mousterian	1183086.667	1.1
Quina Mousterian	475093.3333	1.1
Quina Mousterian II	1655957.143	3.25
MTA	1655957.143	3.25
MTA II	1891080	1.1
Chatelperronian (LC)	1160505	6
Protoaurignacian	281010	9
Early Aurignacian	1655957.143	3.25
Aurignacian	1183086.667	1.1
Gravettian	281010	9
Magdalenian	281010	9

Table 17. Estimated kcal/km^2 and daily movement of prey groups associated with archaeological industries from MIS4 to MIS2. *See table 4 and "Methods used to examine the test propositions" section below for the method used to generate kcal/km^2 and daily movement variables.*

The faunal synthesis provides the data necessary to contextualize the archaeological industries within the heuristic model (Figure **39**). Under this framework, the percentage of individual species within an assemblage is of greatest importance. Synthesized data on the average number of calories per km^2 by species are used as proxies for resource abundance and synthesized data on the daily movements or travel distances by species are used as proxies for resource patterning. In the cases where a single species dominates, kcal/km^2 and daily movement are used without adjustment, and in cases with more than one species, kcal/km^2 and daily movements are averaged between the different species (*see* "Methods used to examine the test propositions" section below for further clarification).

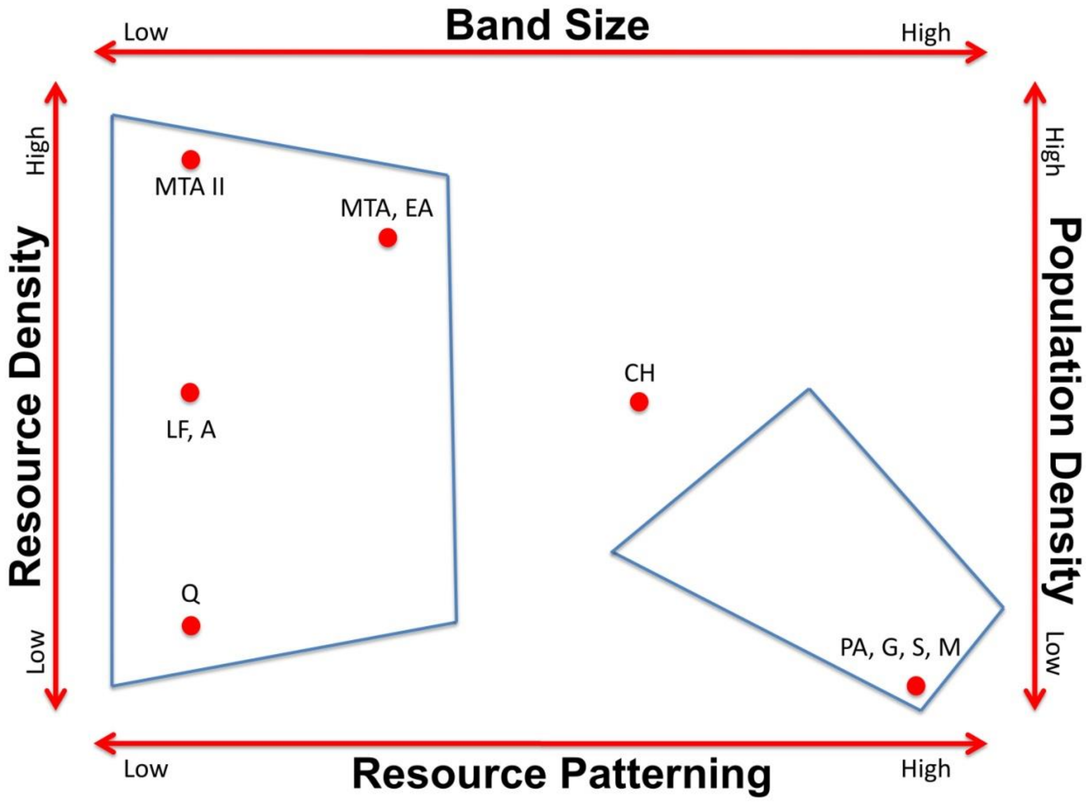


Figure 39. Placement of archaeological industries from MIS4 to MIS2 within the heuristic model.

The results appear to have a good correlation with the predicted models. The MTA, Chatelperronian, Protoaurignacian, Early Aurignacian, and middle and later Upper Palaeolithic cases all fall on an axis between modes 1 and 4. Likewise, all of the Middle Palaeolithic cases fall around modes 1 and 3 while the majority of Upper Palaeolithic cases fall toward mode 4. Given these results, there should be a demonstrable linear relationship between faunal assemblages, as a proxy for resource density and patterning, and lithic material transfer distances at the site level. If such a trend exists and extends through the Middle and Upper Palaeolithic, it would suggest that sourcing patterns and territoriality of Neanderthals and Upper Palaeolithic AMHs were affected by environmental forces in a similar fashion to that of modern hunter-gatherers. Nevertheless, in order to be confident in the application of a band model, there needs to be some level of confidence that Neanderthal and AMH group sizes would have been comparable.

The following sections outline the methods used to examine these potentials. Exploring these questions enables an expansion of the analysis beyond a purely heuristic approach through statistical testing.

Methods used to examine the test propositions

In chapter 2, three propositions were put forward that are concomitants of the assumption that Neanderthal and AMH fission-fusion behaviour was not comparable. The second of these propositions, that Neanderthal territorial areas did not fall within the range observed for modern hunter-gatherers, addressed in chapter 6, was found to be false. Because they require a more involved examination, the first and third propositions are addressed in the succeeding chapters. The following sections outline the methods and used to examine propositions one and three.

Neanderthal and AMH community sizes were not comparable (proposition 1):

The social brain hypothesis (Dunbar 1992, 1996,1998; Barton and Dunbar 1997), as discussed in chapter 5, is based on the established positive correlation between brain size and group size among primates. Simply, parity in brain mass should equate to parity in community size between closely related primate species. Despite having equally sized cranial volumes to Upper Palaeolithic AMH, it has recently been suggested that Neanderthal encephalization was the result of different selective mechanisms and do not imply that their group sizes would have been comparable to those of modern humans (Pearce et al. 2013). Pearce et al. argue that Neanderthal encephalization was the result of selection on the visual cortex paralleled with an increase in orbital size as an adaption to lower light levels in the northern hemisphere. It is, in fact, the larger orbital sizes of Neanderthals that Pearce et al. infer to mean that Neanderthals underwent a separate evolutionary path that resulted in brain expansion specifically within the visual cortex.

Firstly, I address this issue by testing cranial volumes of *H. heidelbergensis*, currently taken as the last common ancestor of Neanderthals and AMHs, against those of a modern human sample population using a two-tailed Student's t-test in order to examine whether large brains were an ancestral trait or a parallel trait shared by Neanderthals and AMHs. This analysis demonstrates that the cranial volumes of H. heidelbergensis fall within the range of normal population variation among modern humans (null hypothesis rejected, $p = 0.42$). Therefore, a modern brain mass was an ancestral rather than a derived trait of Neanderthals and Upper Palaeolithic AMHs. Secondly, I examine whether the larger orbital sizes of Neanderthals could be the result of allometric scaling within the hominin craniofacial region rather than selection on orbital size within the Neanderthal lineage per se. To do this, simple linear regression was employed to test for an association between orbital size and palette breadth, as a feature that captures the general size of craniofacial region, across the *Homo* genus from *H. erectus* to *H. s. sapiens*. This test demonstrates a highly significant correlation ($r^2 = 0.68$, $p = 0.0003$) between orbital size and palette breadth among hominins, which suggests that the larger size of Neanderthal orbits was not likely the result of selection specifically on this feature alone. In conclusion, the proposition that Neanderthal and AMHs community sizes were different is rejected.

Neanderthal and Upper Palaeolithic AMH territorial parameters did not respond in similar ways to environmental pressure (proposition 3):

The territorial areas of hunter-gatherers are highly sensitive to ecological conditions, and prey behaviour is often a powerful structuring force on logistical movements and hunting practices (Layton and O'Hara 2010). For these reasons, I focus my analysis on the relationship between sourcing patterns and prey patterns from the Mousterian to the Magdalenian at the sites of Les Cottés, Geissenklösterle, Hohle Fels, and Les Pradelles. Les Cottés is the most significant of these sites because information on prey and lithic material sourcing is available throughout its transitional sequence (Mousterian > Chatelperronian > Protoaurignacian > Early Aurignacian > Aurignacian).

By focusing on variables that would have affected carrying capacity and territorial areas, this analysis is reflective of Layton et al. (2012) and similar methodological frameworks such as Winterhalder et al. (1988) and Whallon (2006). Whallon's analytical framework, discussed in the previous chapter, is reminiscent of a classic site catchment approach (Vita-Finzi and Higgs 1970). Gamble et al. (2005) have critiqued that such approaches are limited by 'agricultural thinking,' which leads to a bird's eye conceptualization of hunter-gatherer territories as a set of concentric rings of resources. They remind that hunter-gatherer lives are based on an "itinerary: a track, not a catchment" (ibid, 210).

Thus, I take lithic sourcing areas as proxy interaction areas/zones in an approach that I hope is at least implicitly comparable to an analysis of site exploitation areas (Bailey and Davidson 1983). This is to say that sourcing activities were carried out in dynamic landscapes. This is also done in an attempt to recognize the "multidimensionality of adaptive" (Chatters 1987, 338) strategies that were employed. Nevertheless, I have not constructed topographical reconstructions, as the analysis is centred on the change in the percentage of local material at sites over time. However, the primary site, Les Cottés, was chosen partially because its sourcing patterns suggest that it was at the centre of an interaction area throughout the Middle and Upper Palaeolithic (discussed further in chapter 9).

In this analysis I use multiple linear regression to reveal the statistical significance of the relationship between the percentage of local lithic material (as the dependent variable) and prey daily movement/travel distance and calories per km^2 (as independent variables). I set the percentage of local material as the dependent variable because this data is reflective of the typical daily foraging range around sites as discussed in the previous chapter. This information comes from Primault (2003) for Les Cottés, Burkert and Floss (2006) for Geissenklösterle and Hohle Fels, and Costamagno et al. (2006) for Les Pradelles. Furthermore, prey daily travel distance and calories per km^2 are good indicators of the potential time afforded to hominins at a given location. This means that special consideration needs to be given to chronological, palaeoclimatic, and environmental contexts of the assemblages of concern in order to elucidate diachronic trends and environmental factors that would have influenced the socioecology of prey and humans alike.

To derive a variable for daily movement and calories per km^2, I treat each faunal assemblage as a cost budget (Table **18**). Under this framework, the percentage of individual species within an assemblage is of greatest importance. Using Table **18** as an example, in level 9 at Les Pradelles, bison account for just less than 5% of the total assemblage. This accounts for a daily travel budget of ~0.13km or 0.44 (percentage of bison) times 3km (the average distance travelled by bison per day). Bison also account for a calories per km^2 budget of ~90409cal or 0.44 times 2040000 (the number of calories on average per km^2).

Level	**9**	**10**
Bos	39	54
R. tarandus	800	477
C. elaphus	2	2
Equus	39	48
Total	**880**	**581**
%		
Bos	0.044318182	0.092943201
R. tarandus	0.909090909	0.820998279
C. elaphus	0.002272727	0.003442341
Equus	0.044318182	0.082616179
Daily Movement (km)		
(*Bos*) 3	0.132954545	0.278829604
(*R. tarandus*) 1.1	1	0.903098107
(*C. elephus*) 1.1	0.0025	0.003786575
(*Equus*) 3.5	0.155113636	0.289156627
SUM	**1.290568182**	**1.474870912**
Cal/km2		
(*Bos*) 2040000	90409.09091	189604.1308
(*R. tarandus*) 475093.3333	431903.0303	390050.809
(*C. elephus*) 1891080	4297.909091	6509.741824
(*Equus*) 1271914.286	56368.92857	105080.6983
SUM	**582978.9589**	**691245.3799**

Table 18. *Cost budget* for levels 9 and 10 from Les Pradelles.

A statistically significant correlation is taken to imply that ecological conditions (largely the socioecology of prey) underwrote lithic sourcing patterns. The observation of this relationship from the Mousterian through to the Magdalenian would suggest that the response of Neanderthal and Upper Palaeolithic AMH communities to environmental conditions was analogous to extant hunter-gatherers as described by the *band model*.

A Model of non-local lithic sourcing and demography during MIS4-MIS2

To address the sourcing of non-local material within a band model framework, I formulate a linear trend between long distance material (above 100km) and palaeoclimatic data from MIS4 to MIS2, specifically, fluctuations in mid-summer temperature. By assuming than a band sociality system was common to both Neanderthals and Upper Palaeolithic AMHs, I am able to use this model to generate demographic estimates during the Middle and Upper Palaeolithic. Before moving into a discussion of the methodology employed, it would be useful to clarify the justification in choosing to model long distance material transfers against mid-summer temperature.

The analysis of local material sourcing demonstrates that the percentage of local material strongly correlates with prey socioecology. I interpret this relationship as being a result of a fission-fusion response shared by Neanderthals and AMHs to changes in resourcing abundance and patterning. In order to demonstrate that there was a similar effect on long distance lithic material sourcing, as a potential proxy for *regional group* territories, a larger environmental process that would have underwritten prey availability and species turnover needs to be examined. I have therefore chosen estimates for mid-summer temperatures because this factor largely accounts for the growth season of flora and thus fauna.

The health of ungulates is highly dependent on the nutritional welfare of females and juveniles. With red deer, the rut begins in late summer and may go into autumn and calving usually takes place in late spring to early summer (Innes 2011). Both wild and domestic reindeer show a similar pattern of reproductive timing (Ropstad 2000). The seasonality of reproductive cycles means that the fecundity of reindeer and as well as other herbivores in northern latitudes is sensitive to conditions during summer months (Pettorelli et al. 2005) when preferred foods such as grasses and shrubs are capable of providing nutritional levels that allow for rapid rates of growth (Turunen et al. 2009, 815). For example, female body mass and body fat, directly correlates with fertility and therefore the overall fecundity of reindeer (Gerhart et al. 1996) as well as other northern ungulates (Figure **40**). Lee et al. (2000) found that reindeer fecundity positively correlated with mid-summer to autumn warming, which allows for suitable periods of plant growth and ground clearance from heavy snowpack. This is also true for red deer. Favourable summer temperatures allow suitable plant growth so that red deer calves can fatten, which is highly important as they “depend on energy stored in fat and muscle during summer and fall to survive winter” (Innes 2011). Likewise, the reproductive success of red deer females is also dependent on favourable summer conditions (ibid). While harsh winters do affect the survival of dependent juveniles, they do not increase prime-age cow mortality (Johnson et al. 2005, 4). More importantly, Johnson et al. (ibid, 3) note the repeated observation that nutritional abundance during the summer has the greatest effect on the mortality of juvenile cervids.

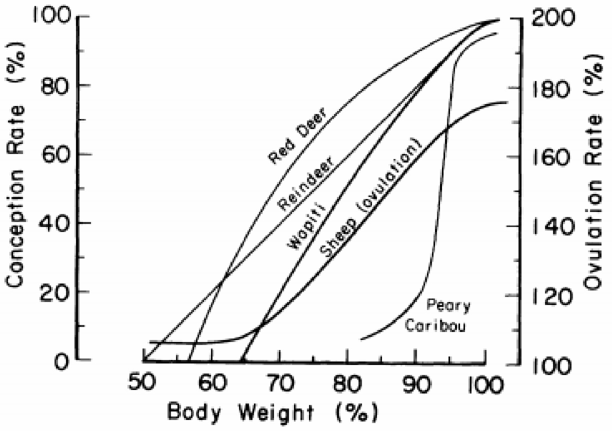


Figure 40. Conception rate and ovulation rate compared to body mass. Copied from White (1983, 381 fig. 3).

One of the few contradictory studies, Kohler and Aanes (2004) found that more temperate summers in Svalbard negatively affected reindeer herd size, as this increased humidity, leading to greater snow cover on the ground. However, this finding may be less applicable to MIS3 and MIS2 when, with the exception of increased humidity during the Hengelo/Les Cottés and Arcy interstadials, the general trend was one of increasing aridity (Stevens et al. 2008, 38-40).

Summer temperature estimates may also capture a major component in the process of turnover in faunal species. Even though mild summer temperatures are conducive to herd fecundity, this is relative to the particular ecological and temperature tolerances of the species in question. Greyson and Delpech (2005) have taken up this point in their analysis of summer temperature estimates from MIS3 and MIS2 and the frequency of reindeer within the Middle and Upper Palaeolithic assemblages from Grotte XVI. Like Banks et al. (2008), they note that changes in air surface conditions only affect the pattern of cervid species, due to differences in temperature tolerances, but larger ecological contexts as well.

Palaeoclimatic effects on prey species would have also played a significant role in the success of human communities both in the short-term and in the long-term. In the short-term or interseasonally, the ratio of fat to meat is an important consideration in element selection by hunter-gatherers in northern latitudes (Speth and Spielmann 1983). Summer conditions would have a short-term, but nevertheless direct, impact in this regard as discussed above. In the longer-term, summer conditions over years or generations would affect the overall success of faunal herds as well as more general ecological processes. These would have a great impact on carrying capacity for humans and, as a result, fission-fusion modes.

Model assumptions:

The following assumptions are built into the model:

1. Middle and Upper Palaeolithic fission-fusion response to environmental pressures were comparable.
2. Long distance material transfers were structured by environmental conditions in a similar way to local material during both the Middle Palaeolithic and Upper Palaeolithic.
3. Therefore, there are no special cases built into the model for differences between the Upper Palaeolithic and Middle Palaeolithic.
4. The changes in the pattern of faunal assemblages during MIS5-MIS2 were underwritten by palaeoclimatic cycles.
5. Palaeoclimatic cycles during MIS4-MIS2 are captured in the summer temperature estimates used in this model. This is because the summer season best accounts for ungulate reproductive success in the northern latitudes.
6. Shifts in prey availability and prey species would have had a highly significant effect on fission-fusion modalities throughout the Middle and Upper Palaeolithic.

Non-local material and demography models:

Following Grayson and Delpech (2005), I construct the model around mid-summer temperature estimates derived from the Grande Pile peat bog (appendix; data provided by J. Guiot). Grande Pile, located in Haute Saône, eastern France, provides a chronologically deep sequence of lacustrine deposits (Guiot 1990). This sequence has been used extensively in palaeoclimatic reconstruction (Guiot et al. 1992; Guiot 1990; Helmens 2014, Bosselin 2003; Bosselin and Djindjian 2002).

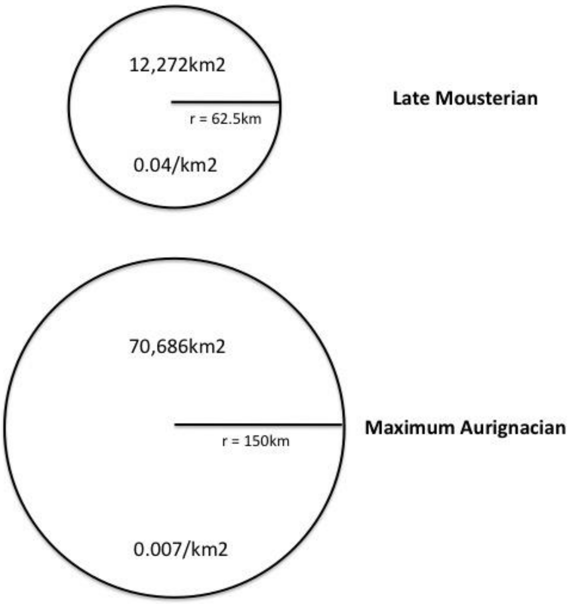


Figure 41. Heuristic of non-local sourcing distances as proxies for community areas during the MP and UP.

To create a simple linear equation that can be applied to the Grande Pile data, I average the temperature estimates from 40,000RCY to 38,000RCY and 37,5000RCY to 36,000KYA, the end of the Middle Palaeolithic and onset of the Upper Palaeolithic, respectively. I then associate these variables with corresponding demographic estimates based on maximum material transfer distances recorded for these periods. Féblot-Augustins (2009) notes that material transfer distances increased during the later Middle Palaeolithic. I accordingly set the maximum travel distance from 40-38,000RCY at 125km. For the onset of the Upper Palaeolithic, the Protoaurignacian and the very earliest periods of Aurignacian (I), I set the maximum travel distance at 300km. During the very earliest Aurignacian, there was a significant increase in material transfer distances compared to before and immediately afterward (ibid). Using Whallon's heuristic model (2006), the maximum transfer distances suggest that population densities were 0.04 agents per km^2 for the final Middle Palaeolithic and 0.007 per km^2 for the earliest phases of the Aurignacian (Figure **41**). I then use the Mesolithic demographic estimate of 0.1 agents per km2 from Milner et al. (2004, 13) as reference point for the density of hunter-gatherer populations in Western Europe under Holocene temperature conditions. Placing the demographic and temperature variables in a linear relationship produces the equation $y = 0.0203x + 0.101$. By applying this equation to the Grande Pile summer temperature estimates, maximum lithic travel distance and demographic predictions can be produced for MIS4 to MIS2 (Figure **42**).

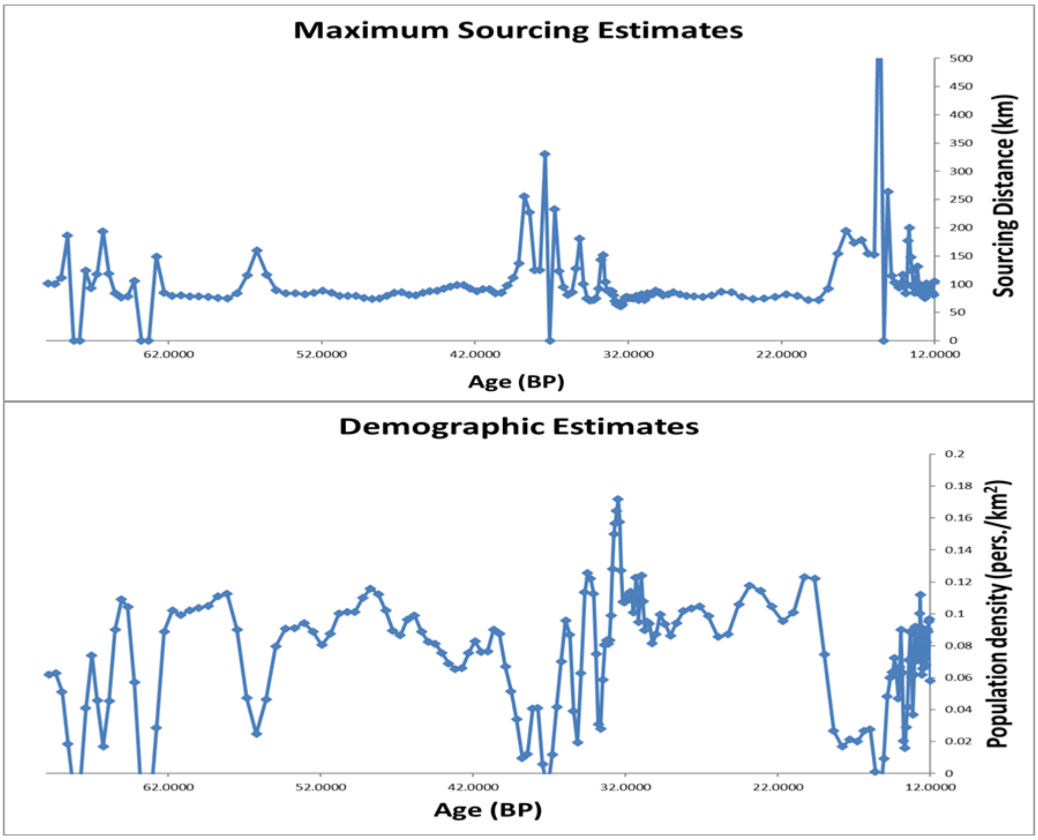


Figure 42. Modelled predictions for non-local lithic sourcing and demography from MIS4-2.

Conclusion

This chapter outlined and discussed the methods used in this thesis to apply the band model to archaeological investigation. In so doing, Neanderthal and AMH social patterns can be examined within a robust theoretical framework. The heuristic and statistical analyses discussed are constructed for this purpose. The following chapters are directed at applying these methods in analyses of palaeoanthropological and archaeological data.

CHAPTER 8

Testing the hypothesis part I: proposition 1

Introduction

This chapter examines sub-proposition 1, group size estimates for Neanderthals and AMHs are not comparable. In so doing, I test for the emergence of modern cranial volume in the human paleontological record and thus the potential physiological mechanism that may have structured the evolution of a band sociality as well as a chronological boundary for the emergence of a modern fission-fusion sociality pattern. Issues concerning the possibility that large hominin brains may have evolved task specific differences after the Middle Pleistocene are examined as well as the role encephalization played in the evolution of human diet and sociality.

In examining the fission-fusion behaviours of Neanderthals and Upper Palaeolithic AMHs, a primary concern is to determine the group sizes of each deme in order to contextualize associated archaeological data within an appropriate fission-fusion model. This is particularly pertinent in the examination of how similar or dissimilar Neanderthal and AMH fission-fusion behaviours and community organization may have been. Reflecting back to chapter 2, there are three propositions put forward that support the primary hypothesis that Neanderthal and Upper Palaeolithic AMH fission-fusion behaviours were not comparable. This chapter tests the first supporting test proposition (Neanderthal community sizes were smaller than those of AMHs) by examining cranial volumes and traits of hominin specimens as well as contemporary humans within the framework of the social brain hypothesis.

A recent study by Pearce et al. (2013) examined whether the *social brain hypothesis* (SBH) can be used to assess Neanderthal and early AMH group sizes. They approached the issue from three angles. First, they examined whether the large brain volumes of Neanderthals and AMHs were an ancestral or parallel trait, concluding that large brains of both demes may have been a result of parallel evolution. Second, they explored whether the parity in Neanderthal and AMH brain size was the result of scaling between body mass and brain mass, suggesting that Neanderthal brains were large simply due to their more massive bodies. Third, they assessed whether Neanderthal and AMH brains evolved under different selective mechanisms. This led from a previous inference that the occipital bunning of Neanderthals may have resulted in smaller frontal lobes compared to AMHs (Dunbar 2009, 231).

Utilizing an earlier study that indicated scaling between orbital surface area and visual cortex size (Pearce and Dunbar 2012), Pearce et al. performed a two-sided t-test on a sample of orbital surface areas from 6 Neanderthal specimens and 10 AMH specimens. Their test demonstrated a significant difference between the two populations (p = 0.011). From this and other physiological differences, they conclude that Neanderthal groups sizes would have been smaller than those of early AMHs. These three issues are comprehensively examined in the following sections in order to address whether Neanderthal and Upper Palaeolithic AMH group sizes were comparable.

Methods

The following section details the methods used to examine Neanderthal and AMH group size within a SBH framework. These include:

1. A statistical testing of the cranial volumes of a sample of *H. heidelbergensis*, cranial volumes against a sample population of extant humans to examine whether large brains are an ancestral trait shared between the Neanderthal and AMH lineages.

2. A statistical analysis and comparison of a sample of Neanderthal and early AMH specimens to determine whether there was a significant difference in the encephalization index, brain to body ratio, of both demes.

3. A linear regression of orbital surface area and palate breadth within the genus *Homo* to examine whether the larger eyes of Neanderthals were the result of craniofacial scaling common to hominins rather than selection on visual cortex *per se*.

Statistical testing of the cranial volume of *H. heidelbergensis* against a modern human population:

Cranial volumes from Middle Pleistocene hominin specimens suggested by Stringer and McKie (1996, 8) and Rightmire (2004) as representative of *H. heidelbergensis* were collected from published materials (*see* Table 19) to test against a modern human sample population. The Middle Pleistocene sample includes specimens from a large geographical distribution (Western Eurasia n= 7, East Asia n=2, Near East n=1, South

Asia n=1, Africa n=9; cranial measurements were available for n=13). The average age of the Middle Pleistocene sample is 416kya. The modern population sample (sample size n=23; measurements taken off MRI scans of North American male volunteers) was taken from Allen et al. (2002). A modern male sample was used as a 'worst case scenario,' as Allen et al. (347) demonstrated that males in their sample had significantly larger brain volumes than their female samples (2-tailed t-test, p < 0.001).

Site	**Volume (ml)**	**Age (KYA)**	**Notes**
Boxgrove		500	Data on age (Stringer et al. 1998, 509)
Bilzingsleben	1200	370	Data on cranial volume (Delson et al. 2004, 132), data on age (Mania and Mania 2005, 98)
Mauer		687.5	Data on age (Mounier et al. 2009)
Arago	1166	450	Data on cranial volume and age (Rightmire 2004, 112 table 2
Petralona	1299.5	425	Data on cranial volume (Stringer et al. 1979, 236), data on age (Harvati 2009, 31)
Jinniushan	1300	275	Data on cranial volume and age (Bae 2010, 78-9)
Dali	1300	280	Data on cranial volume and age (Bae 2010, 77, 85)
Zuttiyeh		250	Data on age (Delson et al. 2004, 738)
Narmada	1288	236	Data on cranial volume and age (Athreya 2011, 130)
Thomas Quarries		501	Data on age (Raynal et al. 2010, 369)
Sidi Abderrahman		390	Data on age (Raynal et al. 2001, 67 table 1)
Bodo	1263	600	Data on cranial volume Bräuer et al. 2004, 115), data on age Rightmire 2004, 112 table 2
Eliye Springs	1210	250	Data on cranial volume (Bräuer et al. 2004, 115), data on age (Bräuer et al. 2003, 200)
Baringo		240	Data on age (Rightmire 1993, 113-114)
Ndutu	1098	400	Data on cranial volume and age (Rightmire 1983, 246, 249)
Florisbad		259	Data on age (Kuman et al 1999, 1410-11)
Saldanha	1225	600	Data on cranial volume (Reed 1954, 883), data on age (Rightmire 2004, 113)

Table continued			
Sima de los Huesos 4	1390	530	Data on cranial volume Rightmire 2004, 112 table 3), data on age (Bischoff et al. 2007); (female) de Castro et al. 2004, 8
Sima de los Huesos 5	1125	530	ibid
Broken Hill I	1310	550	Data on cranial volume (Ash and Gallup 2007, 121), data on age Rightmire 2004, 112 table 2; (35+) de Castro 2004, 11 table 1
Average	**1244**	**416**	

Table 19. Middle Pleistocene Sample Population.

-The taxonomy of the Middle Pleistocene sample population

The taxonomic affinity of Middle Pleistocene hominins is debated, and there has not been a final consensus as to the taxonomy of many specimens. For example, Tattersall (2011) argues that Steinheim, Reilingen, and Sima de los Huesos form one clade and that Mauer, Arago, Petralona, Kabwe, Bodo, Dali, and Jinniushan form another. Recent genetic analyses have produced an even more complex interpretation of the relationship between Middle Pleistocene hominins (Green et al. 2010; Reich et al. 2010, 2011; Meyer et al. 2012, 2013; Prüfer et al. 2014). However, given the genetic proximity of Neanderthals, early AMH, and Denisovans, I feel comfortable including Middle Pleistocene African and Eurasian specimens in the sample population.

Assessing the encephalization index of Neanderthals and early AMHs:

There are physical differences between Neanderthals and early AMHs, which may have resulted from general adaptation to their environmental contexts, Eurasia with the former and sub-Saharan Africa with the latter. Bergmann's rule suggests that Neanderthals should have possessed more massive bodies as a result of adaptation to Eurasia's considerably colder environment compared to equatorial and subequatorial Africa. Cunnane (2006) has likewise concluded that the encephalization index/quotient (brain mass compared to body mass) of Neanderthals was less than that of AMHs because of their greater body mass. However, comparisons between the encephalization quotients of two populations should not be conducted on a general basis, but rather between populations that overlap within a comparable environmental context. Levantine and Near Eastern specimens of early AMHs and Neanderthals, therefore, make the best comparative samples.

Specimen	Body Mass	Cranial Volume
Neanderthal		
Amud 1	87.8	1750
Shanidar 2	78.3	
Shanidar 6	60.6	
Tabun 1	64.1	1270
Average	**72.7**	
AMH		
Qafzeh 3	56.7	
Qafzeh 8	73.2	
Qafzeh 9	63.9	
Skhul 4	73.4	1555
Skhul 5	76.2	1520
Skhul 6	70.9	1585
Average	**69.05**	

Table 20. Levantine Neanderthal and AMH sample population. Data from Trinkaus and Ruff 1999, 1290 table 1 and Aiello and Dunbar 1993, 189 table 1.

To this end, I have collected data for estimated body mass and cranial volumes, where available, for four Neanderthals and six early AMHs (Table 20). Again, I use I two-tailed t-test to examine whether there was a difference in the body mass of Neanderthals and early AMHs in similar environments.

-The palaeoclimatic context of the Near Eastern specimens

The best known Levantine AMHs, the Skhul and Qafzeh individuals, lived during the MIS5 interglacial while the Neanderthal specimens, Tabun, Amud, and Shanidar belong largely to MIS4 and MIS3 (Shea 2008; Hallin et al. 2012; Bar-Yosef and Belfer-Cohen 2013). The fact that the early AMH and Neanderthal specimens belong to different marine isotope stages is problematic. However, the effect of these glacial cycles on the Levant was one of fluctuating aridity rather than changing average temperature (Frumkin et al. 2011), suggesting that selection on overall body mass from MIS5 to MIS3 would have been largely constant.

Craniofacial scaling:

To assess whether the large surface areas of Neanderthal orbits resulted from selection on their visual cortices, I use linear regression to examine craniofacial scaling within the *Homo* genus. This is done to determine if Neanderthal orbital areas were specifically large or if this trait was the potential result of scaling. If the regression analysis demonstrates that orbital areas scale with other cranial features, this would suggest that the Neanderthal phenotype was not necessarily due to selection on visual organs *per se*. Measurements of orbital surface areas were taken from of a sample of hominin skull casts (Table **21**) housed in the Bilsborough Laboratory at Durham University. The orbital surface area measurements were then associated with measurements of palate breadth, as a feature that would be reflective of the general size of the craniofacial area.

Species	Specimen Name	Orbital Height (cm)	Orbital Width (cm)	Orbital Surface Area (cm^2)	Palate Breadth (cm)
Homo heidelbergensis	Petralona 1	3.2	4.3	13.76	4.6
Homo heidelbergensis	Atapuerca 5	3.1	3.5	10.85	4.3
Homo heidelbergensis	Broken Hill 1	3.7	4.5	16.65	4.7
Homo heidelbergensis	Steinheim 1	3.2	3.4	10.88	
Homo heidelbergensis	Florisbad Skull	3	4.4	13.2	4.5
Homo ergaster	"Koobi Fora" KNM-ER3733	3.1	3.4	10.54	
Homo erectus	Sangiran 17	3.4	3.1	10.54	

Table continued

Homo erectus	Dmanisi D2700+D2735	2.7	3.2	8.64	3.3
Homo neanderthalensis	Krapina 3	3.4	3.6	12.24	
Homo neanderthalensis	La Ferrassie I	3.3	3.5	11.55	4.5
Homo neanderthalensis	Gibraltar I	3.6	3.7	13.32	4.1
Homo neanderthalensis	Guattari I	3.3	3.6	11.88	4.1
Homo neanderthalensis	La Chapelle-aux-Saints I	3.5	4.2	14.7	4.4
Homo sapiens	Skhul 5	2.8	3.7	10.36	4.5
Homo sapiens	Cro-Magnon 1	2.1	3.6	7.56	3.6
Homo sapiens	Nahal Ein Gev I?	2.6	3.2	8.32	3.5
Homo sapiens	Predmosti III	3	4	12	4.1
Homo sapiens	Hotu II	2.6	3.1	8.06	3.5

Table 21. Craniofacial sample population.

Test Result

The test results of the three analyses all suggest that the Neanderthal and AMH social groups should have been comparable according to the *social brain hypothesis*. In other words, this analysis found no sufficient ground to assume that Neanderthal group sizes would have deviated from the well-established relationship within Hominidae between neocortical size and group size. More important, perhaps, is that the analysis of the LCA of Neanderthals and AMHs indicates that large brains and potentially large community sizes were ancestral rather than convergent traits. The test results are explained in detail in the following sections.

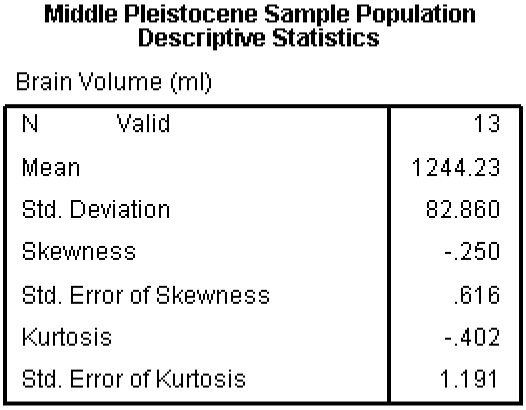
Comparing the *H. heidelbergensis* sample population to a modern human sample population:

The hypothesis that Middle Pleistocene cranial volumes would not be expected from an extant human population is rejected (t=0.81 p=0.42). According to this analysis, the emergence of a modern brain mass occurred within the Middle Pleistocene prior to the divergence of Neanderthals and AMHs around 270kya (Green et al. 2010, 718), conforming to previous conclusions (Rightmire 2004). Comparing *Homo heidelbergensis* and extant humans demonstrates no statistical difference (whereas *H. heidelbergensis*/*H. erectus* p=0.001; *H. erectus* sample taken from Aiello and Dunbar 1993, 188 table 1). This implies a difference between the energetic expense of *H. erectus* and encephalized Middle Pleistocene hominins.

The modern sample population presents a mean cranial capacity of 1273.6ml (S.D.=115ml). The Middle Pleistocene sample for which volume measurements are available is small (n=13), presenting a mean capacity of 1244.23ml. This is an issue that may affect the validity of the test results. Nevertheless, the standard deviation of the hominin sample is less than that of the modern sample (S.D.=82.8). However, the validity of the result must be tested, as the sample population size (n=13) does not fulfil an assumption of a normal distribution.

-Skewness of the sample population

The validity of the test result is dependent on whether the frequency distribution of each sample being tested (the modern human sample and the Middle Pleistocene sample population) deviates significantly from a normal distribution. The modern sample population (n = 23) is nearly of substantial enough size to conform to the central limit theorem (CLT) therefore the normality of this sample distribution is not of concern. The Middle Pleistocene sample, however, is too small (n = 13) to conform to a CLT assumption, and its normality must be tested.



Middle Pleistocene Sample Population
Descriptive Statistics

Brain Volume (ml)

N	Valid	13
Mean		1244.23
Std. Deviation		82.860
Skewness		-.250
Std. Error of Skewness		.616
Kurtosis		-.402
Std. Error of Kurtosis		1.191

Table 22. Sample Statistics.

The skewness of the Middle Pleistocene sample population is -0.250, demonstrating that there is some skewness in the distribution of the sample. The distribution is weighted toward a value higher than the mean. However, the skewness value (-0.25) of the sample falls within the standard error range of skewness (-1.23 to 1.23, as the std. error of skewness = 0.616; *see* Table **22**). Further, the Kurtosis value (-0.402, std. error = 1.19) also implies that the normality of the sample distribution is not affected significantly enough to question the validity of the test results.

Body mass and encephalization index of Neanderthals and early AMH:

The statistical comparison of the Neanderthal and AMH samples using a two-sided, two-tailed t-test suggests that the overall body mass of the two demes was comparable ($p = 0.63$) in similar environmental contexts. The comparison of the cranial volumes of the two sample populations is not permissible due to a limitation of data. However, scaling suggests that the encephalization quotient of both populations was the same. For example, taking the cranial volume/body mass relationship of Skhul V, the largest AMH in the sample, as a benchmark, the estimated body mass of Amud I would be 87.7kg, only 0.1kg less than the body mass estimate of this specimen. In other words, if the body mass of Skhul V were scaled up to the body mass of Amud I, then the estimated cranial volume would be 1751cc or only 1cc larger than the current estimate for Amud 1. Scaling also accounts for the cranial volume of Tabun 1, the smallest cranial volume out of the two sample populations. If the benchmark were scaled down to the body mass of Tabun 1, then the estimated cranial volume would be 1278cc or 8cc larger than the current estimate for Tabun 1. Therefore, it appears that the encephalization quotients of Neanderthals and AMH were comparable to each other, suggesting that the larger body mass of Neanderthals alone cannot account for the parity in brain size with AMHs.

Orbital surface area and craniofacial scaling in the hominin lineage:

The linear analysis demonstrates a very strong correlation between palette breadth and orbital surface area within the *Homo* genus (Figure **43**, $r^2 = 0.68$, $p = 0.0003$). This relationship suggests that the difference between Neanderthal and AMH orbital surface areas is an effect of scaling rather than selection for larger eyes within the Neanderthal lineage.

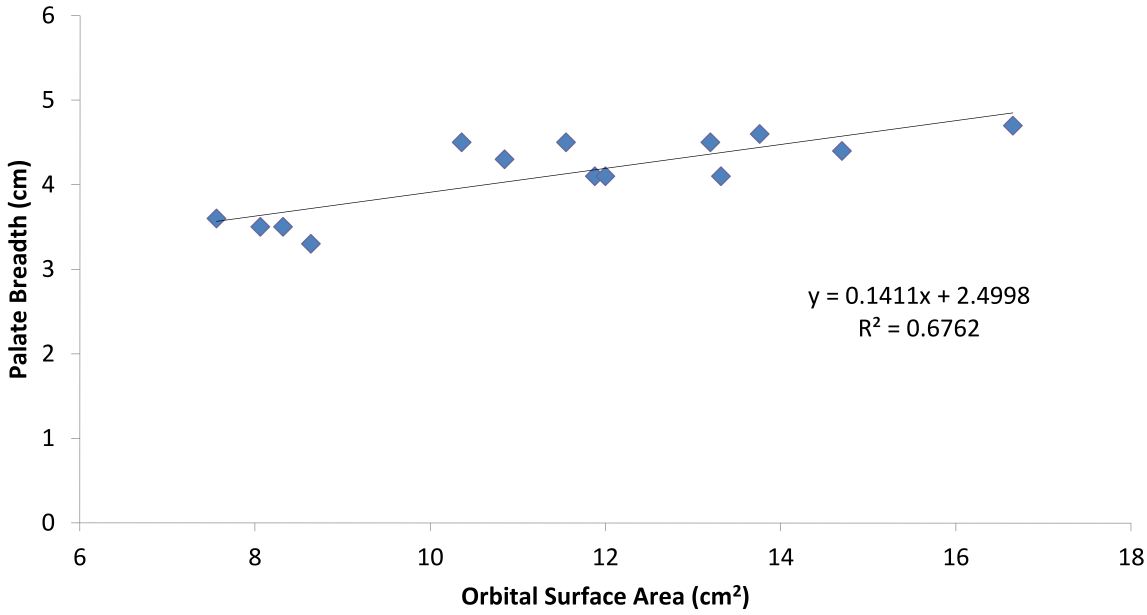


Figure 43. Bivariate relationship between palette breadth and orbital surface area within the *Homo* genus.

-Neanderthal and AMH facial structure

A brief examination of the differences between Neanderthal and AMH facial anatomy further suggests that larger size of Neanderthal eyes was not the result of specific selection. Lieberman et al. (2002) in their examination of Neanderthal and AMH morphology describe a set of derived and ancestral traits of the two demes in an attempt to better define AMH morphology. They note that a derived trait of modern humans is a much smaller face relative to cranial size compared to both Neanderthals and archaic African hominins (ibid, 1136). This observation fits well with the correlation between orbital size and palette breadth, which suggests that scaling accounts for the observed difference in Neanderthal and AMH eye size. More importantly, the reduction in the size of AMH faces results in a 10-15% difference in the "supero-inferior height" of the upper face (ibid, 1137), meaning that relative to the rest of the hominin lineage AMHs have shorter orbital openings rather than Neanderthals possessing longer orbits. Likewise, the shorter height of AMH orbits accounts for the difference between Neanderthal and AMH orbital surface areas (height p = 0.001; width p = 0.39).

Accordingly, adjusting for this difference in the facial length of Neanderthals and AMHs (Table **23**) eliminates the statistical significance (p = 0.16) of the difference between Neanderthal and AMH orbital surface areas.

Species	**Specimen Name**	**Catalogue #**	**Orbital Height (cm)**	**Orbital Width (cm)**	**Orbital Surface Area**
Homo neanderthalensis	Krapina 3	HOM-213	2.96	3.6	10.64
Homo neanderthalensis	La Ferrassie I	HOM-247	2.61	3.5	9.13
Homo neanderthalensis	Gibraltar I	HOM-205	3.13	3.7	11.58
Homo neanderthalensis	Guattari I	HOM-204	2.87	3.6	10.33
Homo neanderthalensis	La Chapelle-aux-Saints I	HOM-202	3.04	4.2	12.78
Homo sapiens	Skhul 5	HOM-313	2.8	3.7	10.36
Homo sapiens	Skhul 5	HOM-313	2.8	3.7	10.36
Homo sapiens	Cro-Magnon 1	HOM-314	2.1	3.6	7.56
Homo sapiens	Nahal Ein Gev I?	HOM-201	2.6	3.2	8.32
Homo sapiens	Predmosti III	HOM-206	3	4	12
Homo sapiens	Hotu II	HOM-242	2.6	3.1	8.06

Table 23. Adjusted orbital measurements. Neanderthal orbital height divided by 1.15.

The examination of Neanderthal, AMH, and Middle Pleistocene hominins refutes the suggestion that the parity of Neanderthal and AMH brain sizes was the result of evolutionary convergence. There is, accordingly, no reason to assume that the parity in Neanderthal and AMH cranial volumes was a result of selection on different regions of the brain between the two demes. The comparison of the Middle Pleistocene sample population with the modern population demonstrates that Neanderthals and AMHs inherited a modern brain size from their LCA. Whatever task specific selective mechanisms led to a modern brain size thus had their greatest effect prior to the divergence of the Neanderthal and AMH lineages. There appears to be no reason to assume that Neanderthal and AMH brain organization was inherently different, and there is no reason to downgrade Neanderthal community size estimates. Therefore, under the SBH, Neanderthal and AMH communities are anticipated to contain the same number of agents.

Discussion

The emergence of a modern brain size during the Middle Pleistocene indicates that the social ecology of Neanderthals and AMHs should have been comparable. This is because the modern human brain carries specific energetic costs that would have had a direct effect on community organization and other social dynamics. The dietary and social implications of the test results are discussed in the following sections.

Dietary implications:

The emergence of a modern brain mass is perhaps one of the most significant physiological traits to have evolved within the *Homo* genus. This is because the brain is one of the most energetically taxing organs in the human body (Aiello and Wheeler 1995). This fact has been recognized for many years. For example, Hockett and Ascher in their seminal thesis, 'The Human Revolution,' note that the human brain, while composing only about 2% of the entire body, consumes up to 12% of the total blood supply (1964, 145). Nearly as long ago, O'Brien and Sampson (1965) recognized that the large size of the human brain placed certain constraints on the human dietary regime such as increasing that need for lipid consumption during childhood development.

Above other physical traits, the emergence of a modern brain volume is important to understanding the evolution of the human dietary regime for two reasons. First, the evolution of a larger body mass is known to have occurred prior to the evolution of a modern brain volume (Aiello and Key 2002). Further, a large body mass has evolved multiple times within Hominidae, but balancing a large brain within a large body seems to be a limiting factor (Milton and Demment 1988). Second, out of the whole of the human anatomy, the brain is the sole organ to carry a greater energetic cost than would be anticipated for that of another hominid of similar mass (Aiello and Wheeler 1995).

Therefore, the human brain consumes more calories than the brains of other hominids. For these reasons, Aiello and Wheeler (ibid) as well as Milton and Demment (1988) argue that the evolution of a modern cranial volume would have resulted in a dietary regime based around high tier resources such as meat and starch rich foods.

-Expensive tissue hypothesis

The *expensive tissue hypothesis* argues that, as the human brain increased in relation to body mass, there was an evolutionary trade off in which splanchnic organ mass reduced to conserve overall basal metabolic rate (BMR). The shortening of the digestive track would have shifted the human diet away from a pongid-like regime toward higher tier, more easily digestible, resources such as meat and underground storage organs. Access to a high quality diet is vital for children "as most wild plant foods would not be capable of supplying the protein and micronutrients children require" (Milton 2003, 3891). In contrast with the difficulty children have with digesting plant foods, all mammalian infants possess the ability to absorb whole proteins—something that human adults cannot do (Matthews 1971, 30). This would have placed an acute pressure on encephalized hominins to exploit greater levels of animal derived protein, as "[e]ighty-seven percent of basal metabolic rate" in neonates is devoted solely to brain development (Milton 2003, 3891). However, there is an alternative theory to this hypothesis, but it likewise argues for a similar shift in the human dietary regime.

Navarrete et al. (2011) question the empirical grounds of the *expensive tissue hypothesis*. Reviewing a large sample of mammalian species, they argue that there is little support for the negative relationship between splanchnic organ mass and brain volume when measurements are controlled for body fat. Though this study poses serious problems for the *expensive tissue hypothesis*, it does not contradict the dietary implication of the hypothesis. What Navarrete et al. argue in effect is that human physiology adjusts for the increased expense of a large brain by storing energy reserves in the form of adipose tissue.

The accumulation of body fat requires access to easily digestible foods that are high in fats and/or glucose. Regardless of the exact physiological processes that have led to a uniquely human dietary regime, encephalization has played a central role.

-*The biochemistry of the human diet*

A brief review of the amino acids essential to cellular mitosis helps to explain why the hominin diet shifted toward high tier resources. Animal cell growth as well and nitrogen balance requires the consumption of "13 amino acids, 8 vitamins, 6 ionic species, glucose, and serum protein" (Eagle 1959, 432). Of the thirteen amino acids, eight (isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine) are considered essential, and five (arginine, cysteine, glutamine, histidine, tyrosine) are needed to maintain cell growth in lab samples (ibid). For humans, at least two of the non-essential amino acids, histidine (Holt and Snyderman 1961) and glutamine (Lacey and Wilmore 1990), are in fact necessary during human ontogeny and other periods of rapid tissue growth and regeneration. Humans are particularly attracted to foods rich in glutamate because it activates the *umami* taste receptors, giving foods a savoury quality (Lindermann et al. 2002; McCabe and Rolls 2007). A key reason for this attraction is the glutamine/glutamate cycle, which forms the chemical basis for neural transmission (Daikhin and Yudkoff 2000).

Fauna would have been the best sources of histidine and glutamine/glutamate for Palaeolithic humans. According to the analysis of Block et al. (1965, 421, table 2), animal flesh contains about three times the concentration of histidine than do domesticated plant resources. Likewise, the highest sources of glutamine and glutamate are fish and meat (de Araujo et al. 2003; Kurihara and Kashiwayanagi 2000). Not surprisingly, human breast milk is very high in glutamine and glutamic acid (Agostoni et al. 2000).

However, this is not to overestimate the importance of meat. Floral resources, particularly plant storage organs (seeds, tubers, taproots, bulbs) contain many if not most of the needed amino acids (Young and Pellett 1994). Roughly 60% of the diet of modern hunter-gatherers is derived from floral resources (Layton and O'Hara 2010), and globally, plant based foods constitute about 65% of the human diet (Young and Pellett 1994). Nevertheless, the reliance on cultigens by extant hunter-gathers means such figures are probably not reflective of Palaeolithic subsistence regimes. For example, in Layton and O'Hara's survey of hunter-gatherer diets (2010), those with the highest plant based contribution (90-70%), Mbuti, Nukak, Ju/Hoansi, and G/wi, either engage directly in cultivation or rely heavily on trade with neighbouring farmers (Hart and Hart 1986, Politis 1996, Lee 1972, Solway and Lee 1990). This is in contrast to hunter-gatherers who neighbour ranchers rather than farmers such as the Western Desert aboriginals whose diet can contain up to “80-90%” animal derived products (Cane 1987, 432). The availability or access to cultigens seems to play a significant role in the amount of floral based resources consumed by human communities. This is because domestic plants have a much higher nutritional value and digestibility than their wild counterparts.

The cell walls of plants, which encapsulate the nutrient rich portions of cells, are mostly cellulose, which humans cannot fully digest (Spiller et al. 1980). Plant foods, therefore, often need to be processed and cooked. There is a downside to this as cooking results in the degeneration of the essential amino acid component of plant foods (Abdel-Rahman 1983, Purcell and Walter 1982). Alternatively, humans can rely more heavily on animal derived foods. Animal cells have a cell membrane composed of digestible lipids and proteins (Yeagle 1989) rather than a cell wall. However, protein, the main component of animal derived foods, requires a glucose or fat based energy source in order to be digestible. If glucose or fat is not available, digesting lean meat will result in a depletion of the body’s fatty tissues, leading to nitrogen poisoning, increased risk of morbidity, lower fertility, and potentially even death (Bilsborough and Mann 2006, 129). This is preventable if the animal derived resource includes enough fat. However, except for in arctic marine environments, animal fat is seasonally limited (Speth 1991). The deleterious effect of lean meat can be overcome through the inclusion of cooked starchy plants (Wrangham and Conklin-Brittain 2003) often in the form of below ground starchy organs, tubers and roots (Hoover 2001).

-Environmental Patterning of a high tier diet

The natural occurrence of high tier resources is limited and seasonally dependent. Unfortunately for human communities, the time of greatest abundance of starchy, glucose rich plants overlaps with the time when terrestrial fauna have an optimal balance of fatty deposits. As Speth and Spielmann note:

> In late winter and spring, reliable alternative resources such as small mammals, fish, and stored plant foods often became scarce or unavailable, and hunter-gatherers had to rely on large ungulate species for a major part of their diet. It is precisely at this time of year, however, that a diet composed largely or entirely of ungulate meat may lead to caloric and other nutritional deficiencies because the

> ungulates themselves are experiencing nutritional stress and becoming fat-depleted. (1983, 3)

The flexible cohesiveness of human communities like those of other fission-fusion species is structured spatially and temporally in accordance with the timing of resource availability. Gravitation toward a diet based around high tier resources has subjected humans to the acute effects of scramble and contest competition. Encephalization then posed a problem for the human lineage because increases in brain volume necessitated the acquisition of low availability, high value foods. This shift in the human diet "posed its own cognitive problems for tracking social relationships" (Layton and O'Hara 2010, 104).

Social Implication:

The evolution of a modern brain mass had a knock on effect that altered the human dietary regime. The associate physiological effect was either a reduction of total splanchnic organ mass or an increased necessity for fatty tissue deposits—or both. Either case would have resulted in the high tier pattern of the human diet. This would have posed certain social problems for the human lineage since such foods are environmentally rare and often highly patterned.

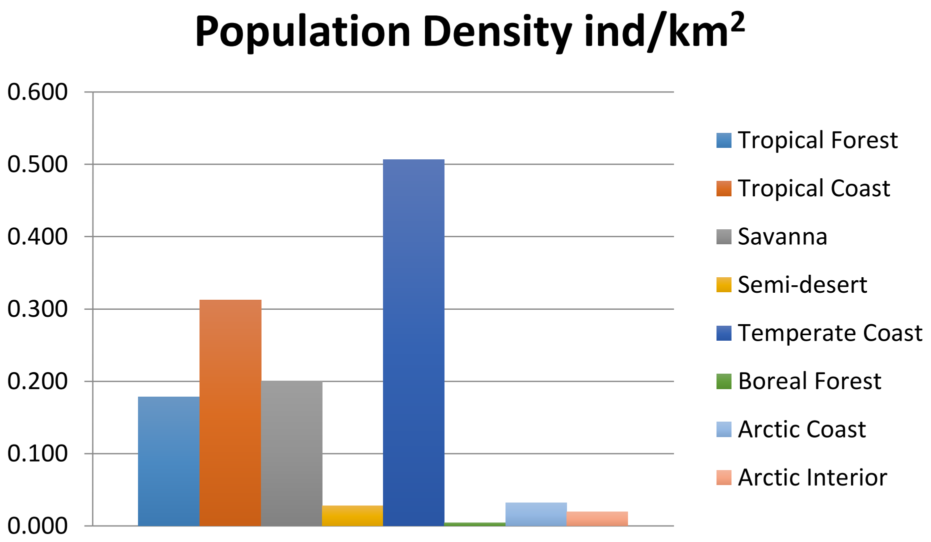


Figure 44. Hunter-gatherer population density by ecology. Data from Layton and O'Hara (2010, 88-9 table 5.2).

According to Layton and O'Hara (2010), the gravitation toward high tier resources particularly terrestrial fauna has resulted in the low population densities seen among modern hunter-gatherers (Figure **44**). Pleistocene humans would have been subject to similar carrying capacity constraints due to the limited natural occurrence of fauna and high tier floral resources. The lowering of population densities would have meant that a pongid like troop structure was no longer tenable.

-Troops to bands

A quick examination of the theoretical time budget of a troop community living at a modern hunter-gatherer population density demonstrates the maladaptive nature of such a scenario. Assuming certain optimal conditions (Table **24**), a troop of 150 hominins living at the average hunter-gatherer savannah population density of 0.2 persons/km^2 would amount to a total territorial area of 750km^2.

Conditions	Estimates
Population density	0.2/km2
Community size	150 individuals
Daylight hours	12
Average walking speed	5km/hour
Social Grooming Time	40% of active hour

Table 24. Conditions assumed in troop sociality model.

Using Whallon's model (2006), this equates to a territorial diameter of 30.9km with a radius of 15.45km (Figure **45**). A troop structure necessitates regular physical contact between community members. The primary reason for this is social grooming to forage and reinforce inter-agent alliances, which help the troop to function as a cohesive whole. According to Aiello and Dunbar (1993), a human like primate would have to spend 40% of its waking hours engaged in social grooming under a troop social system. Assuming an ideal 12 hours of day light, this would equate to 4.8 hours of social grooming time. Troop members foraging at the periphery the troop territory would have to travel at least 15.45km in order to engage with the greater community through physical contact. Assuming an average walking speed of 5km/hour, this would equate to 3.09 hours of walking and a daily travel time of 6.18 hours.

Such agents would be subject to nearly 11 hours of time spent simply engaging in activities solely dedicated to maintaining the troop. They would likewise only be afforded about 1 hour of daylight hours for subsistence activities. Caring for and transporting dependent young would significantly increase travel costs further reducing the extremely limited foraging time. Raising the community size to a more ethnographically salient 500 individuals increases the territorial area to 2500km^2. Under such a condition, disbursement alone for peripheral members would cost 12.6 hours, exceeding daylight hours and leaving no time for subsistence activities and social interaction. The solution to such a conundrum would be a fissioning of the troop into longer lasting subgroups, a band sociality.

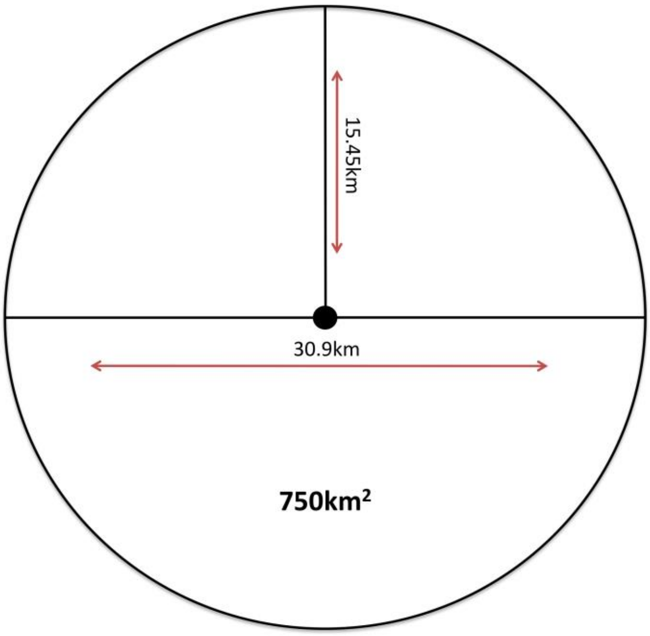


Figure 45. Heuristic model of troop territory.

The exact process of selection that led from a troop to band based sociality is difficult to speculate. However, a parsimonious assumption may lie with pressures placed on past communities to successfully feed dependent offspring (Stiner 2002, 2-3). In this case, it can be imagined that prior to the emergence of a modern rate of encephalization, there may have been times in which hominin communities may nevertheless have been subject to a dietary regime composed of high tier resources. These periods would have been brought about by the necessity to feed pregnant females and neonates. Reproductive success would have been placed not just on the individual, but groups of individuals to sustain higher rates of carnivory and greater inclusions of starch and glucose rich floral. As a result, population densities would have to decrease, structuring a new fission-fusion mechanism that could enable a greater flexibility in community cohesion across time and space. This new social system is best described as a band sociality.

Conclusion

There is no statistical difference between the expected cranial volumes for Middle Pleistocene hominins and extant human populations. Though it is true that the mean of the modern human sample (1273.6) is slightly larger than the mean of the Middle Pleistocene sample, Beals et al. (1984, 302) note in a review of modern human populations that mean cranial sizes can range from "1085 to 1518" and that non-pathological measurements ranged from "900 to 2100". This cautions against using cranial volumes, particularly after the Middle Pleistocene, as evidence for cognitive differences between hominin communities. To drive the point home, according to *The Lancet* report by Witelson et al. (1999), Albert Einstein's post-mortem brain volume was measured at 1230g—about 14 grams smaller than the Middle Pleistocene average.

Likewise, the analysis of the cranial facial differences between Neanderthals and modern humans failed to support the assumption that there would have been significant structural difference between the brains of the two demes, and therefore probably no functional difference either. This should be anticipated as it has previously been demonstrated (Azevedo et al. 2009) that the differences between the human and chimpanzee brain are largely explained by allometric scaling. The human brain is in essence a 'scaled up' primate brain, meaning that mass alone accounts for the differences in overall cortical mass and total number of brain cells between humans and *Pan troglodytes*.

The failure to demonstrate a difference in either the size or structural function between the brains of Neanderthals and AMHs means that the supporting proposition that *Neanderthal and modern human communities sizes would have been different* must be rejected. This suggests that the parameters of Neanderthal and AMH fission-fusion behaviour should have been comparable, and therefore, the third supporting proposition can be legitimately examined. Most importantly, if a modern rate of encephalization was a trait possessed by the last common ancestor of Neanderthals and anatomically modern humans, then variance in material transport patterns should be reflective of an adaptive fission-fusion response to local environmental condition, a product of carrying capacity.

CHAPTER 9

Case study part I: Les Cottés

Les Cottés: a primary case study

This chapter provides a summation of research conducted at the site of Les Cottés since the mid-20th century. Published excavation results are detailed and synthesized. This entails a discussion of the site stratigraphy, cultural sequence (and lithic material sourcing), chronology, and past environmental and palaeoclimatic context.

Les Cottés is significant both for its archaeological and palynological sequences. Archaeologically, the site provides a remarkable record of the early Upper Palaeolithic. Palynologically, the site records the climatological instability of this period. Both afford a unique window into the cultural and environmental contexts of the Middle to Upper Palaeolithic transition. The following sections provide background information on the site of Les Cottés.

Site Introduction:

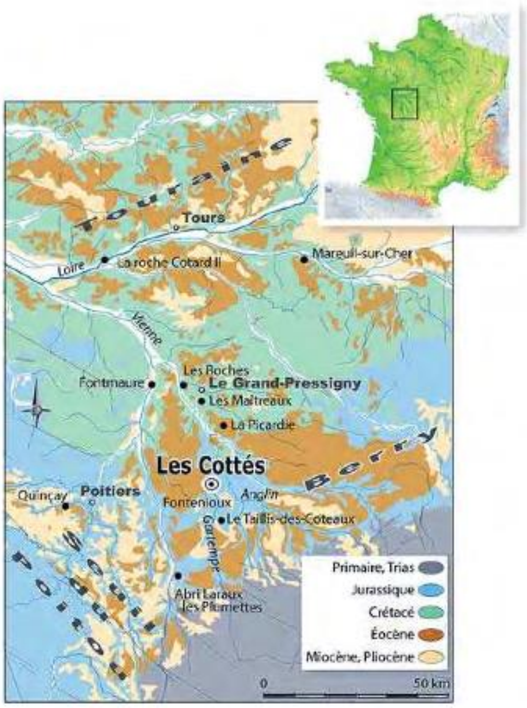


Figure 46. Location of Les Cottés. Copied from Roussel and Soressi 2013, 284 figure 1.

Les Cottés or La Grotte du Cottés is a cave site located in Saint-Pierre-de-Maillé, Vienne France, near the border of Poitou, du Berry, and la Touraine (Soressi et al. 2010, 222). The cave lies on the Gartempe River (Figure **46**) and is geographically proximal to the Palaeolithic complexes of the Anglin Valley (Soressi et al. 2010, 222). The cave itself (Figure **47**) is part of an ancient karstic system cut into a Jurassic limestone bedrock at the start of a rise in the landscape above an alluvial plain formed by the Gartempe River (Soressi et al. 2009; Roussel and Soressi 2013, 284). The 'porch', the sediment directly in front of the cave entrance, contains a four-meter thick deposit of archaeologically rich stratigraphy (Frouin 2013, 186). This stratigraphy also contains a rich palynological sequence that has been highly informative in reconstructing the eponymous *Les Cottés interstadial*. This interstadial has been thought to correspond with Greenland interstadial (GI) 8 (Soressi et al. 2010), however, this association may not be accurate as is discussed further in this chapter.

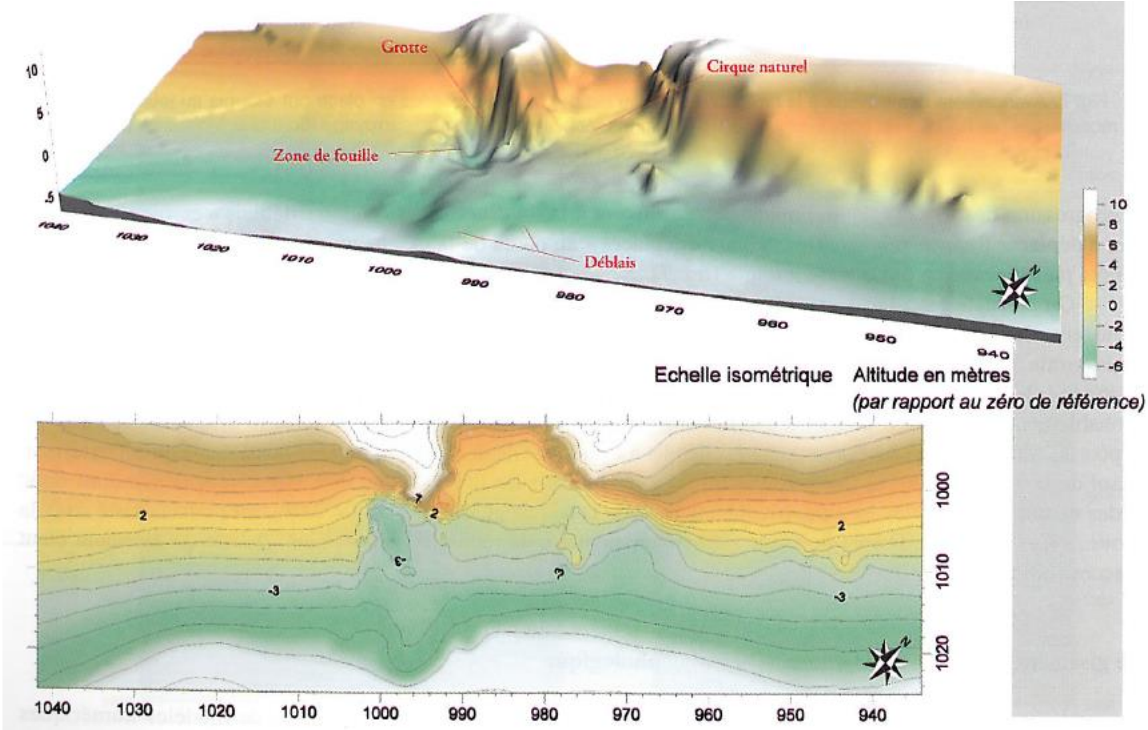


Figure 47. Geophysical overview of the Les Cottés. Copied from Soressi et al. 2009, 18 fig. 9.

The archaeological sequence is notable for containing superimposed horizons of the Mousterian, Chatelperronian, Protoaurignacian, and Early Aurignacian (Soressi et al. 2010, 221-2). The site's Chatelperronian level contains the type assemblage for the "Evolved" Chatelperronian or the Chatelperronian with Cottés Points. This horizon is also notable for bearing one of largest recorded assemblages of the Chatelperronian (Harrold 1981).

Beyond the uniqueness of the site's Chatelperronian assemblage, Les Cottés is highly significant in the understanding the evolution of the Aurignacian. One reason for this is the superposition of the Protoaurignacian above the Chatelperronian horizon. Together with the Arcy-sur-Cure complex, the Protoaurignacian assemblage from Les Cottés (Figure **48**) demonstrates the occurrence of this industry well beyond its assumed coastal, Mediterranean context (Barshay-Szmidt et al. 2012, 18).

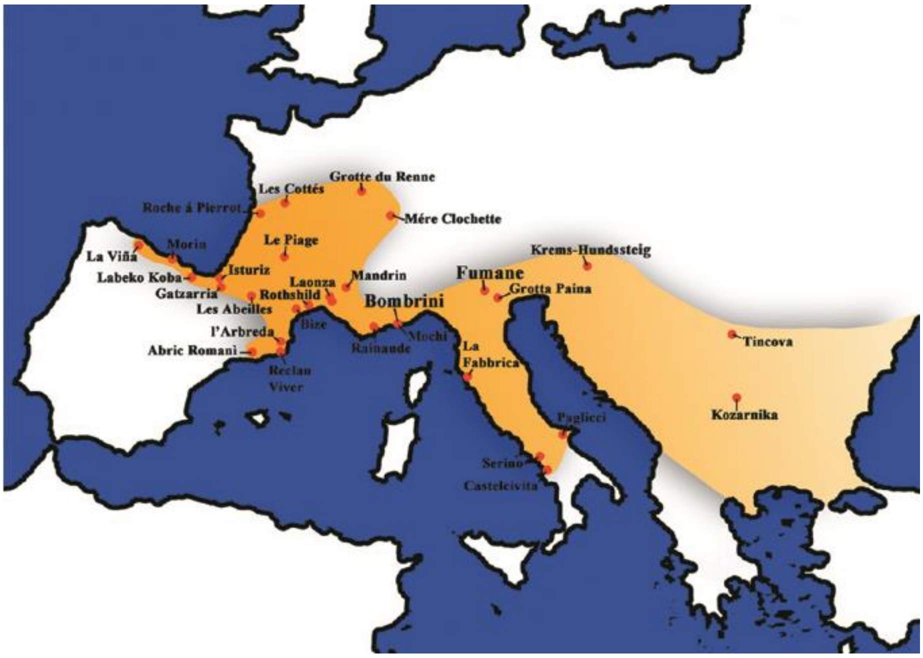


Figure 48. Spatial distribution of the Protoaurignacian. Image modified from Benazzi et al. 2015, 18 fig. S1 OSM Nature.

Second, the site's sequence is one of the few to contain an Early Aurignacian superpositioned over the Protoaurignacian; the other sites being Morin, Labeko Koba, Riparo Mochi, Esquicho Grapaou, Gatzarria, Isturitz, La Vina, and Le Piage (Higham et al. 2013, 3). The nearby sites of Fontenioux and Les Plumettes contain a comparable series of archaeological horizons, late Mousterian, *evolved* Chatelperronian, and Aurignacian (Soressi et al. 2010). Fontenioux is the sister site to Les Cottés, being located only a couple hundred meters away. Les Plumettes lies some distance to the south and unfortunately, for the sake of archaeological comparison, is largely a palaeontological site (Jaubert et al. 2011 *citing* Primault 2003).

Research History:

Excavation of Les Cottés began in the late nineteenth century. From 1880 to 1881, R. de Rochebrune started digging within the cave as well as in front of the cave entrance. He recorded an archaeological sequence comprised of "Pre-Solutrean," Aurignacian, and Mousterian horizons (Soressi et al. 2010, 222). De Rochebrune recorded the discovery of a human cranium within the Aurignacian cultural level. The morphology of the skull is argued to be modern, however, the exact stratigraphic position of the skull is uncertain today (ibid, 223). This research resulted in de Rochebrune's colourfully named *Le Troglodytes de la Gartempe: Fouille de la grotte des Cottés*.

Modern Archaeological methods were applied to the site with the start of Louis Pradel's excavations during the second half of the last century. Pradel excavated some twenty cubic meters of sediment (Talamo et al. 2012, 176) from the *porche*, the area in front of the cave entrance. Using Peyrony's cultural systematic, Pradel described the occurrence of an evolved form of the Chatelperronian, which he named the *Perigordian II*. The fossil director of this *industry* is the Cottés Point, a Chatelperronian-like point made on a very uniform blade blank (Pradel 1959; 1963). In 1972, Lévêque began a systematic sedimentological and palynological analysis at the site under the direction of Pradel. This research led to the identification of a sterile stratigraphic level between the previously identified evolved Chatelperronian and Protoaurignacian horizons. Further palynological analysis by Bastin confirmed the occurrence of an interstadial event, the Les Cottés interstadial, recorded in the site sequence between the Mousterian and Chatelperronian levels (Bastin et al. 1976). The Les Cottés interstadial, while understood to be a warmer and wetter event, is nevertheless considered an unstable interlude toward the end of MIS3 associated with the Chatelperronian technocomplex (Lévêque 1997). The interstadial has been argued to fall between Wurm II and III, corresponding to the Greenland interstadial 8 (Soressi et al. 2010, 226). However, recent dating (Talamo et al. 2012; Jacobs et al. 2015) of the Mousterian and Chatelperronian levels calls this assumption into question, as I discuss later on in this chapter.

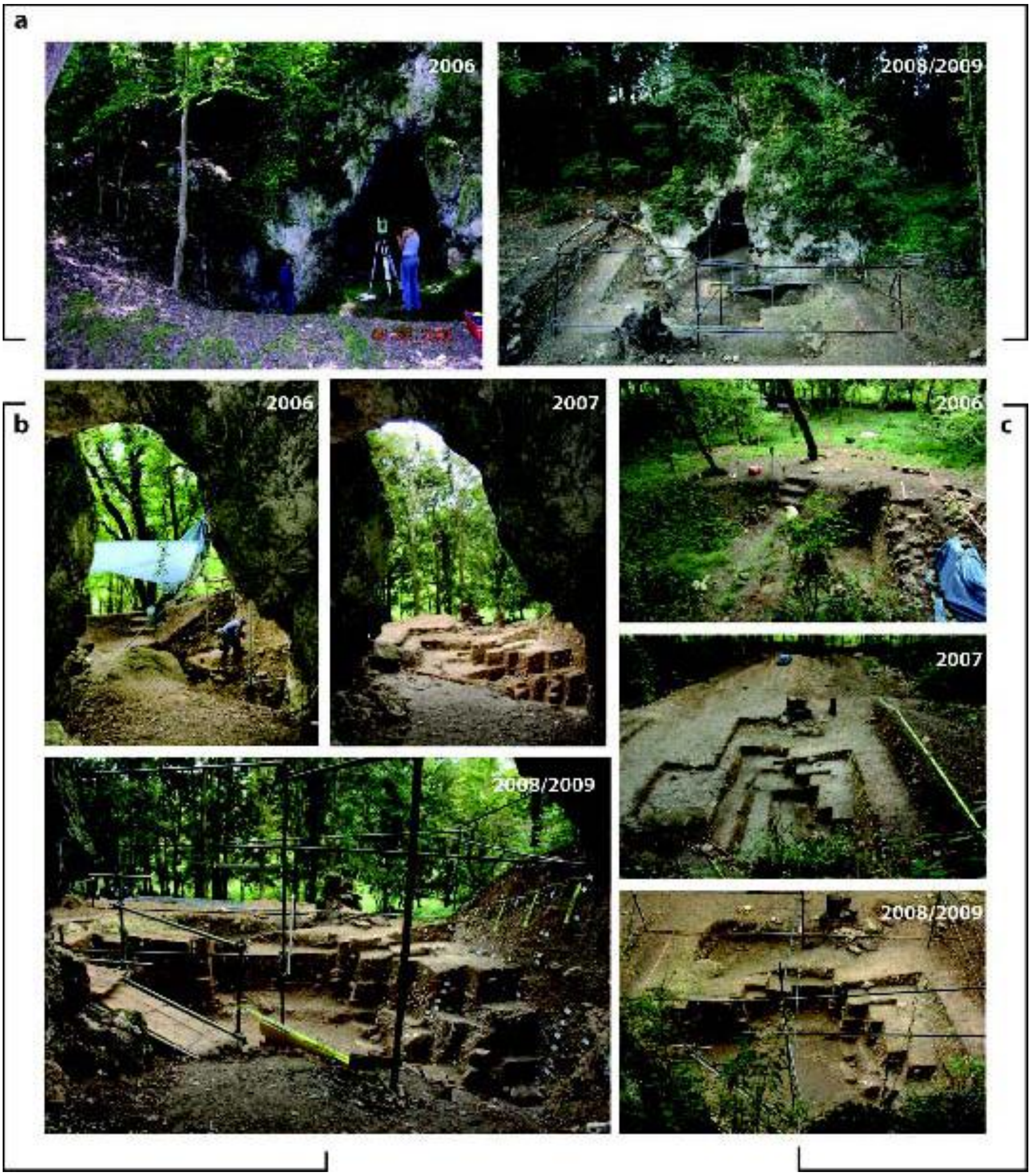


Figure 49. Photographic overview of the excavation at Les Cottés. Copied from Roussel and Soressi 2009, 5 fig. 1.

Starting at the turn of the century, Jérôme Primault began a lithographic survey of siliceous deposits within the surrounding landscape. He then analysed the lithic assemblages from Pradel's excavations to determine sourcing strategies during the different archaeological phases (Primault 2003). Starting in 2006, excavations commenced again at Les Cottés under the direction of Marie Soressi and are still ongoing. The current excavation area is located within the *porche* or open-air (beyond the drip line) potions of the site. Excavation is limited to a thirteen-meter long section (Figure **49**) left untouched by Pradel, which forms a semi-circular profile (Talamo et al. 2012, 176). The retesting of the site has entailed three primary objectives: to determine site formation, sedimentation processes, to validate previous observations of the known archaeological horizons, and to analyse the different behaviours of the human groups that occupied the site (Soressi et al. 2010, 227). This chapter attempts when possible to synthesize the findings of Pradel's excavations with the available publication from Soressi's ongoing work at the site.

Site Stratigraphy

There are two stratigraphic schemes for Les Cottés, the first from Pradel's excavations, and the from Soressi's work. Three horizons of greatest importance to this study according to Pradel's schematic (1959, 1961) are *niveau* G, Mousterian, F, Chatelperronian, and E, early Aurignacian. Both Pradel's excavation area and ongoing retesting are located within the *porche* of the rock shelter. This semi-open to open area has a slope of ten degrees in the opposite direction of the cave entrance with each stratigraphic horizon expanding in the direction of the slope (ibid). Each of the archaeological assemblages pertaining to the transition are separated by sterile zones. The retesting of the site has confirmed Pradel's previous assertions of the stratigraphic integrity of the transitional assemblages. The recent investigation under the direction of Soressi has produced an updated site stratigraphy that affirms the majority of Pradel's observations.

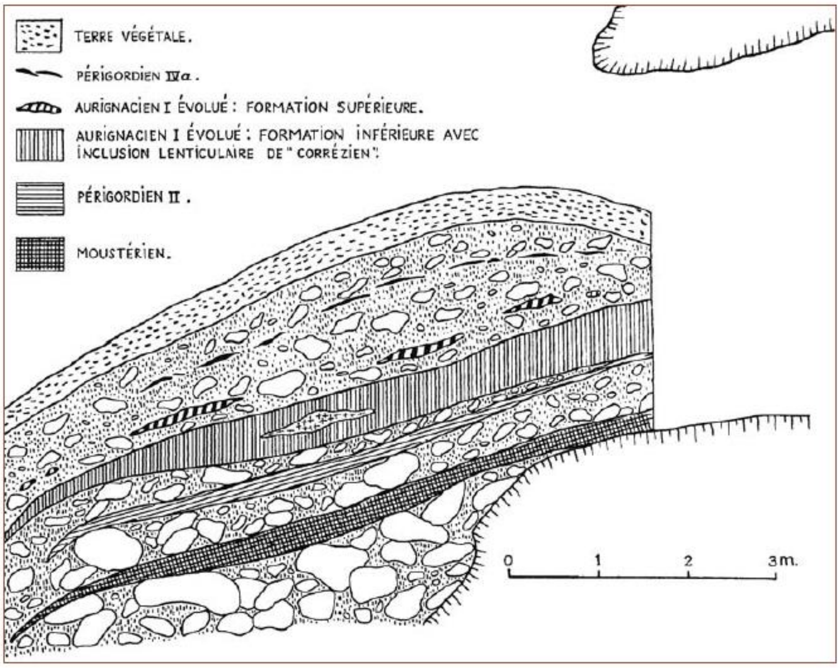


Figure 50. Pradel's stratigraphic profile of the Les Cottés sequence. Copied from Pradel 1961, 231 figure 2.

According to Pradel's (1959) system, the stratigraphy of the *porche* (Figure **50**) is divided into nine horizons. Five of the horizons contain archaeological material with the whole sequence spanning the late Mousterian to the Gravettian, or Evolved Perigordian under Pradel's interpretation of Peyrony's cultural chronology. The ongoing retesting of the site follows a similar stratigraphic system (Figure **51**). In general, the site stratigraphy is composed of horizons of sandy clay diamicton with blocks of limestone scree present throughout (Soressi et al. 2010, 229). Level D and level/unit 03 (even perhaps the first four levels) were subject to colluvial processes, interjecting *mud* into the parent material during sediment formation (Frouin 2013, 187). The underlying sediments were not subject to this process. The following level descriptions attempt to unify both systems while relying on Pradel's stratigraphic scheme.

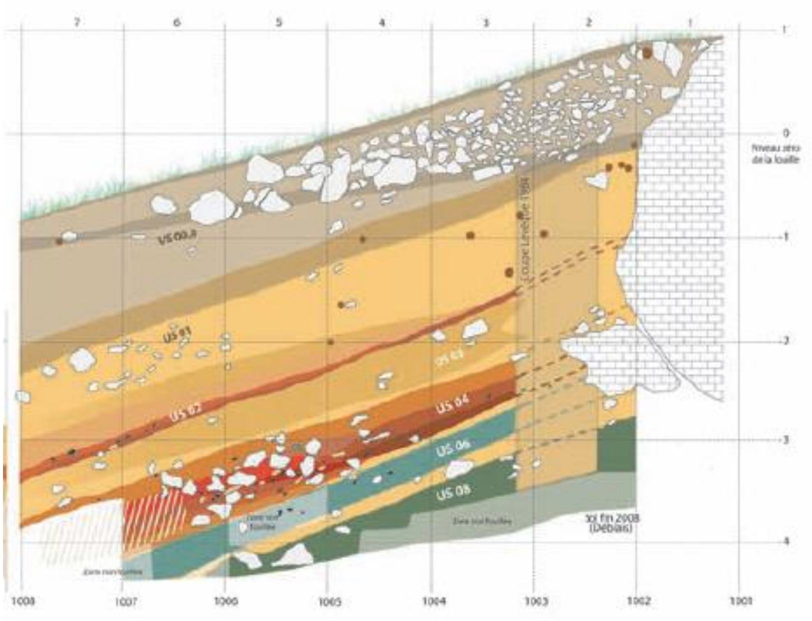


Figure 51. Current stratigraphic profile of the Les Cottés sequence. Copied from Soressi et al. 2010, 229 fig. 8.

Level A:

This horizon is comprised of organic sediment corresponding to an O or A soil horizon. It extends from the surface of the site (Z), into the cleared topsoil, down to 30cm on average. Level A does not correspond to a specific horizon designation under the retesting program or ongoing excavations. Neither the excavations under Pradel nor the recent excavations have recovered archaeological materials from the surface of the site.

Level B:

The sediment is composed of sand and clay interspersed with limestone scree from the surrounding karstic environment. This horizon corresponds to unit 00 under the stratigraphic system according to the current excavation program. It appears to be a subsoil or an E/B soil horizon of the organically rich Level A. No archaeological material has been recovered from the level. According to Pradel, this level is about 40cm thick on average.

Level C:

This level corresponds to unit 01 under the new research program. Unit 01 is notably thick (nearly a meter in some sections for example in *test unit* 4 *see* Figure 51) A small number of diagnostically Gravettian artefacts were recovered from this level by Pradel. The cultural affinity of this level has not been affirmed by the current research team. This level is composed of a similar sandy clay matrix to that of the overlying Level B. Pradel does not distinguish between the two on sedimentological grounds. However, as this level contains an archaeological assemblage with an assumed normal depositional history occurring beyond the dripline of the cave, the level must in effect be a buried paleosol of some sort.

Level D:

This horizon is composed of a sandy clay matrix with limestone boulders. According to Pradel, this is the thickest horizon in the sequence at 85cm on average but see the following *Unit 03* summary below. This level corresponds to Unit 02 under the current excavation program. Toward the base of the horizon, archaeological material has been recovered that is diagnostic of the Early Aurignacian though Banks et al. (2013) question, due to the small assemblage size, whether these materials truly belong to the Early Aurignacian. Pradel (1961) noted that the cultural material is associated with a blackened, anthropic, and possibly burnt sediment. In contrast to the underlying as well as the superpositioned strata, level D does not vary extensively in its average thickness (Soressi et al. 2010, 229), which may suggest a more uniform formation process.

Unit 03:

This horizon was not recorded by Pradel and was thus most likely incorporated into the overlying Level D. It is composed of an argillaceous matrix 30cm thick on average (Soressi et al. 2010, 229) and is largely sterile (artefacts n=118, ~4% of the underlying lithic assemblage according to Talamo et al. 2012, 117 table 2). The lithics are diagnostically similar to those of level E and the provenience of the majority of the lithic tools (n=116) are located above the interface of Unit 3 and Level E (Soressi et al. 2010, 229). Thus the anthropic materials, both lithic and osseous, are thought to have been derived from the underlying level E.

Level E:

Pradel (1961) describes this as an archaeological horizon presenting an Early Aurignacian assemblage with some archaic elements, or Corrézien pockets at the base. This level corresponds to unit 04 under the retesting program (Soressi et al. 2010). The current site investigation has refined the observational description of this horizon, producing a far more complex picture of the initial Aurignacian occupation of the site. The horizon has been subdivided into a lower and upper unit on archaeological, biochronological, and sedimentological grounds. Lower unit 04 is a clay rich gravel matrix that is brown in colour. Upper unit 04 consists of similar matrix components, but is reddish in colour possibly from ochre staining (Rigaud et al. 2014). In the north section of the site, a sterile level separating the two subunits has been observed (Soressi et al. 2010, 230).

Level F:

This is a sterile stratum that separates the Aurignacian and Chatelperronian archaeological levels. It is about 15cm thick on average. The level is composed of a sandy clay matrix with limestone scree interspersed throughout. Lévêque (1997, 282) noted that level F contains a significant amount of scree compared to the rest of the sequence.

Level G:

This level is a deposit formed by human and carnivore activities. The cultural material belongs to the Chatelperronian tradition. Around 22% of the fauna shows evidence of anthropic modification while over 10% of shows carnivore modification (Talamo et al. 2012, 178).

Level H:

This is a sterile stratum about 35cm thick that separates the Mousterian and Chatelperronian archaeological levels. As discussed later on in this chapter, this level records the Les Cottés interstadial event. The stratum is composed of a sandy clay matrix with limestone scree throughout.

Level I:

This level is primarily a deposit formed by human and carnivore activities that lies above the bedrock interface in some portions of the site. The excavated lithic artefacts are from the Mousterian tradition. Results from the recent excavation indicate that about 15% of the faunal assemblage shows carnivore modification while only 17% show signs of anthropic modification (Talamo et al. 2012, 178).

Archaeological Sequence

Pradel (1959) assigned the archaeological sequence at Les Cottés to five different cultural traditions. These were, descending in stratigraphic order:

- level C presenting sparse inclusions of lithics assigned to the Gravettian
- level D presenting a limited number of Aurignacian tools
- level E containing a relatively large deposit of Early Aurignacian and *Corrézien* materials
- level G presenting Chatelperronian materials
- level I containing a late Mousterian assemblage with scrapers and denticulates.

According to Pradel (1961; 1963), the Chatelperronian assemblage from level G is exceptional for its highly uniform, backed elements especially the *pointe des Cottés*.

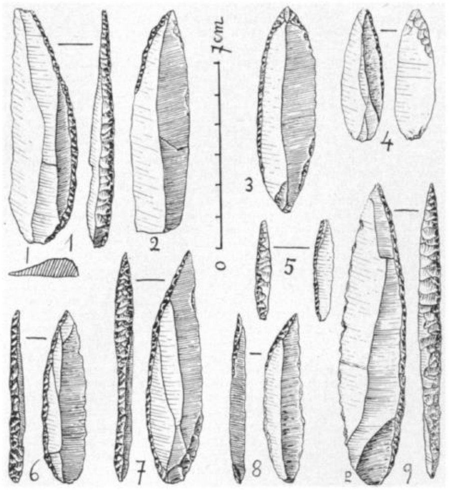


Fig.1

Figure 52. Pointes des Cottés. Copied from Pradel 1963, 583 fig. 1.

Pradel (1963, 586) argued that that Cottés points differ from the typical Chatelperronian type by being formed on lighter and more rectilinear blanks and their quality of retouch, which extends down their length. He (1961, 1963) considered that the quality and form of the curved knives and backed blades (Figure **52**) from level G suggested an intermediate type between the Chatelperronian and the Gravettian.

As with the site stratigraphy, the organization of the archaeological horizons has altered under Soressi's direction. These changes are twofold: the cultural affinity of level C is now considered uncertain and level E has been divided into two archaeological horizons, a Protoaurignacian level superimposed by an Early Aurignacian level (Soressi et al. 2010).

As noted in the previous section, Pradel (1959; 1963) did not divide level E (unit 04) into sublevels. He did, however, observe pockets of *Corrézien* artefacts at the base of level E. The unusual term, *Corrézien,* was proposed by Pradel to describe the similarity of some of the level E artefacts with the early Upper Palaeolithic complexes of Corréze, France, which contain the type-sites for Protoaurignacian *fossiles directeurs* such as Grotte de Dufour as well as Font-Yves (Bouyssonie 1944; Demars 1992; Pesesse 2011). In effect, Pradel's Corrézien corresponds to a Protoaurignacian systematic. In this way, the recent observations do not differ too greatly from those of Pradel. However, Pradel did not treat his Early Aurignacian and *Corrézien* artefacts as separate entities in the tabulation of lithic and faunal materials from level E until the 1960's (Pradel 1963, 250 table 3). By contrast, upper unit 04 and lower unit 04 have been excavated and quantified separately from the onset excavation by the current research team.

While lithic artefacts largely account for the cultural materials at Les Cottés, bone tools are documented in the Aurignacian levels with some even showing decoration (Leroy-Prost 1979). The Chatelperronian does not lack bone tools, but by contrast, the assemblage is more limited and poorly preserved (Pradel 1961). Symbolic artefacts in the form of body ornaments have been recovered from the Early Aurignacian levels (Rigaud et al. 2014). So far ornaments have not been recovered from the Chatelperronian at Les Cottés, however, lumps of pigments have (Dayet et al. 2014).

Level C (Gravettian?):

Pradel (1959; 1961) records limited traces of *Périgordien évolué* artefacts from this level. He recorded a total of 38 tools. The current research team does not consider this level an archaeological horizon and only 45 lithic artefacts have been recovered from excavations between the field seasons of 2006 to 2009 (Talamo et al. 2012, 177 table 2).

Level D (Aurignacian):

Primault (2003, 204) describes a typical Early Aurignacian typology for Pradel's level D collection with strangulated blades, blades with Aurignacian retouch, end scrapers on blades, and carinated scrapers. According to Pradel's excavations, scrapers are the most common tool type with carinated and end scrapers being highly represented. Burins are also very common while retouched blades account for the highest quantity of leptolithic tools. In all, Pradel records 209 tools from level D, which he classified as an Aurignacian I assemblage.

The current research team has upheld Pradel's typological definition of level D (Soressi et al. 2010; Talamo et al. 2012; Welker et al. 2015). As excavation and post-excavation analysis are ongoing, the published descriptions of the lithic assemblage recovered from 2006-2009 vary. The current research team records 1133 to 1183 total lithic elements for level D, but less than 3% (n= 35) of these were retouched tools (Talamo et al. 2012; Roussel and Soressi 2013, 286 table 1). There were a further 7 cores, 23 flakes, 370 blade blanks, 696 pieces of debitage, and 2 hammerstones (Roussel and Soressi 2013, 286 table 1). Oddly, a microlithic component is conspicuously absent from the 2006-2009 assemblage (ibid).

Level E (Protoaurignacian and Early Aurignacian):

Stratigraphic level E contains two separate archaeological levels, which, as noted, have been subject to different methodological treatment over the course of the past sixty plus years of excavation. Scrapers comprise the largest tool category from Pradel's excavations for both levels, accounting for over 70% of all tools with end scrapers comprising a significant portion (Primault 2003, 190). However, the largest category of scrapers is *grattoirs carénés* some of which may have been discarded cores rather than tools. Soressi et al. (2010, 229) note that the lithics from level E appear unworn and lack patina. Fine mesh screening has also recovered a large portion of small pieces of debitage, which is a further testament to preservation of the lithic assemblage from this level (ibid).

-Upper level (Early Aurignacian)

Pradel (1961, 250 table 3) records 1,437 tools for the upper level or *Aurignacian I inférieure*, meaning the lower Early Aurignacian level within the site sequence rather than the lower horizon with level E. *Rabots* and various types of scrapers are by far the largest categories. These are followed by burins and retouched blades.

As with level D, the ongoing nature of the current research at Les Cottés means that there are slight discrepancies in the published tabulation of lithics recovered since 2006. There have been between 2245 to 2840 total lithic elements and between 112 to 121 retouched tools excavated between 2006-2009 (Talamo et al. 2012; Roussel and Soressi 2013, 286 table 1). Most of these tools are retouched blades, but Aurignacian retouch is infrequent, accounting for roughly 5% (Talamo et al. 2012). Retouched blades are followed by end scrapers and retouched bladelets (ibid). There are at least a further 17 cores, 30 flakes, 745 blade blanks, 1318 pieces of debitage, 2 blade cores, 15 bladelet cores, and 14 hammerstones (Soressi and Roussel 2013, 286 table 1).

-Lower level (Protoaurignacian)

Pradel's *Corrézien* assemblage is relatively small with only 60 retouched tools (1961, 250 table 3). Pradel (1961, 251) describes the *Corrézien* as a lens less than a meter and half in diameter within the Aurignacian I deposit distinguished from the surrounding level by its darker sediment colour. Typologically, the artefact assemblage differs from the Aurignacian I by the presence of Dufour bladelets subtype Dufour (ibid). This Dufour subtype along with the Font-Yves point are still considered to be type fossils of the Protoaurignacian (Zilhão 2006, 11). Carinated scrapers, end scrapers, and *rabots* are the most common artefact type from Pradel's assemblage, which are closely followed by Dufour bladelets (Pradel 1961, 250 table 3).

According to the current research team, the provenience of the Protoaurignacian deposit differs significantly from Pradel's description. Excavations from 2006 to 2009 have shown that the Protoaurignacian occurs as a discrete deposit at the base of level E separated by sterile sediment from the superimposed Early Aurignacian level (Soressi et al. 2010). There is also a significant difference in the tabulation of relative assemblage size. Since 2006, 5992 to 6466 total lithic elements have been recovered of which 191 to 195 have been retouched tools (Talamo et al. 2012, Roussel and Soressi 2013, 286 table 1), making the Protoaurignacian the largest assemblage out of the entire sequence. Beyond the formal tools, there are at least 2,421 blade and bladelet blanks, 156 flakes, 3152 pieces of debitage, 47 cores, and 25 hammerstones (Soressi and Roussel 2013, 286 table 1).

Level G (Chatelperronian):

According to Pradel (1959), level G contains a unique Chatelperronian assemblage with a highly uniform blade production. Pradel labelled the assemblage an *Evolved* Chatelperronian or Perigordian II (1959; 1961). Of the 552 tools, backed elements and burins are the most common types followed by retouched blades and bladelets (Pradel 1961, 242 table 2). There is a large mousteroid component to the assemblage with many retouched flakes (n = 127) of which about half are denticulates (ibid). Given the separation of the Mousterian and Chatelperronian by the sterile level H, the inclusion of Mousterian artefacts such as denticulated flakes and bifaces (ibid) seems to be a genuine characteristic of the assemblage. This stands at odds with 'evolved' nature of the assemblage and contradicts recent arguments that the Chatelperronian is solely leptolithic industry (Bordes and Teyssandier 2011).

Unlike level E, there does not appear to be a significant conflict between Pradel's description of the Chatelperronian assemblage with that of the current research team's findings. However, the *evolved* nature of the assemblage is yet to be confirmed (Soressi et al. 2010). Though there are no signs of edge wearing the assemblage appears not to be as well preserved as the Aurignacian horizon due to the slight patination of some artefacts (ibid, 229). Since 2006, 1,980 to 2,273 total lithic elements have been recovered of which 79 to 83 have been retouched tools (Talamo et al. 2012; Roussel and Soressi 2013, 286 table 1). Of this, there are at least 592 blade blanks, 79 flakes, 1,168 pieces of debitage, 23 cores, and 39 hammerstones (Roussel and Soressi 2013, 286 table 1). As with Pradel's level G assemblage, backed pieces are the most common type (ibid, 289 table 2).

The assemblage does not show signs of edge wearing do to taphonomic process but some of the material does show some patination (Soressi et al. 2010, 229).

Level I (late Mousterian?):

The cultural affinity of the level I assemblage has not been well defined. It has been described as a *Moustérien sans biface* (Pradel 1961), a Quina Mousterian (Bastin et al. 1976), and a Charentian Mousterian (Frouin et al. 2013). The limited recovery of artefacts (n = 350) from the most recent excavations (2006 onwards) has not permitted a clarification of this issue (Talamo et al. 2012, 176-7).

According to Primault (2003, 143), Pradel's excavations resulted in the recovery of 882 lithic elements of which the majority are debitage flakes. The majority of the tools recovered scrapers with convex scrapers being the most frequent (Pradel 1961, 234 table 1). Utilized flakes are the next most common type followed closely by denticulated flakes (ibid). Beyond these, elongated levallois cores and backed pieces are present (Primault 2003, 143). The typological description of Pradel's assemblage fits well with the current synthesis of the final Mousterian in France (Jaubert et al. 2011), which concludes that a denticulate Mousterian or levallois Mousterian with scrapers preceded the Chatelperronian.

Synthesis:

1. The high percentage of denticulates within the Chatelperronian assemblage expresses an affinity in tool type and perhaps behaviour with the Mousterian occupation of the site. The denticulate and retouched flake tool components of the Chatelperronian assemblage could be argued to reflect a mousteroid characteristic, detracting from Pradel's (1959; 1963) argument that the level G assemblage represents an *evolved* Chatelperronian. However, Primault (2003) does not see a mousteroid characteristic to this assemblage.

2. Retouched tools only account for a small portion of the lithic assemblage from the Chatelperronian to the Aurignacian varying only from 3% to 4 % of the assemblage.

3. Though the discontinuous nature of the Level D archaeological deposits, the low number of artefacts recovered may actually be due in part to a lower occupation intensity.

4. The typological similarity of the level D assemblage to the upper level E assemblage adds weight to the assumption that this assemblage belongs to the Early Aurignacian (*contra* Banks et al. 2013a).

Material Sourcing

Les Cottés lies within the general area of Grand-Pressigny, which is famous for its flint and jasper sources (Pradel 1970; Primault 2003). During later prehistoric periods, especially toward the end of the Neolithic, Grand-Pressigny flint was extensively traded across Western Europe as far as the Netherlands and Switzerland (Plisson et al. 2002). Even though flint is available in the alluvial deposits of the Gartempe less than a kilometre from Les Cottés, lithic sources are not available within the immediate vicinity of the site itself (Primault 2003, 139). Situated equidistant to many of the regional flint outcrops and deposits (Figure **53**), Les Cottés lies at the centre of the lithic sourcing areas of the Mousterian through to the Gravettian occupations of the site.

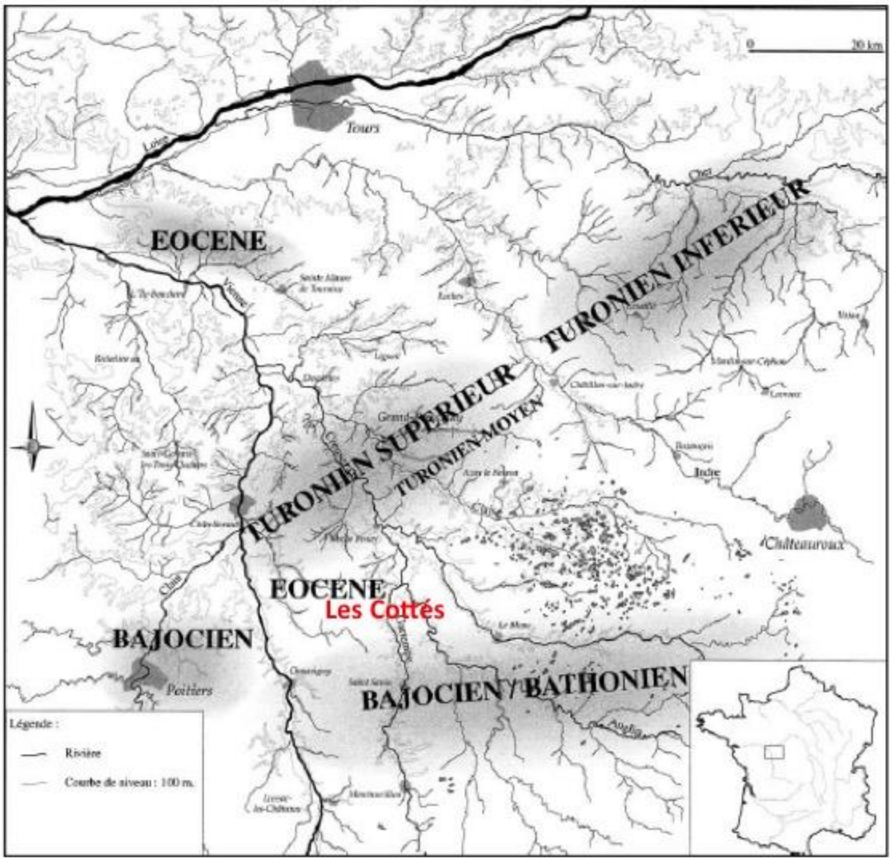


Figure 53. Principle lithic sources within Vienne, France. Copied from Primault 2003, 31 figure 4.

Information on the geological origin of the Les Cottés lithic artefacts comes almost entirely from Jérôme Primault's 2003 doctoral thesis. Primault's doctoral study entailed a comprehensive analysis the lithological landscape of Vienne, France, coupled with an examination of the Palaeolithic assemblages within the surrounding region. Despite the thoroughness of Primault's thesis, there are three caveats to be mindful of: only the assemblages from Pradel's excavations were available at the time, the examined level E assemblage contains both Protoaurignacian and Early Aurignacian artefacts in accordance to Pradel's excavation plan, and there is some confusion within Primault's thesis regarding the stratigraphic position of the Aurignacian levels. The first issue is something that is unfortunately not rectifiable.

The second concern is also difficult to overcome. However, Soressi et al. (2010) provide a very brief discussion, re-examining the sourcing of material from Level E, that suggests that the Early Aurignacian artefacts are more frequently made on non-local materials compared to the underlying Protoaurignacian. The final issue is rather minor. In short, Primault erroneously placed Pradel's upper and lower Early Aurignacian levels within the same stratigraphic horizon, when in fact the former belongs to Level D and the later to level E. **The following level information on the**

sourcing of the lithic materials from Les Cottés is sourced from Primault 2003 except where otherwise cited.

Level C:

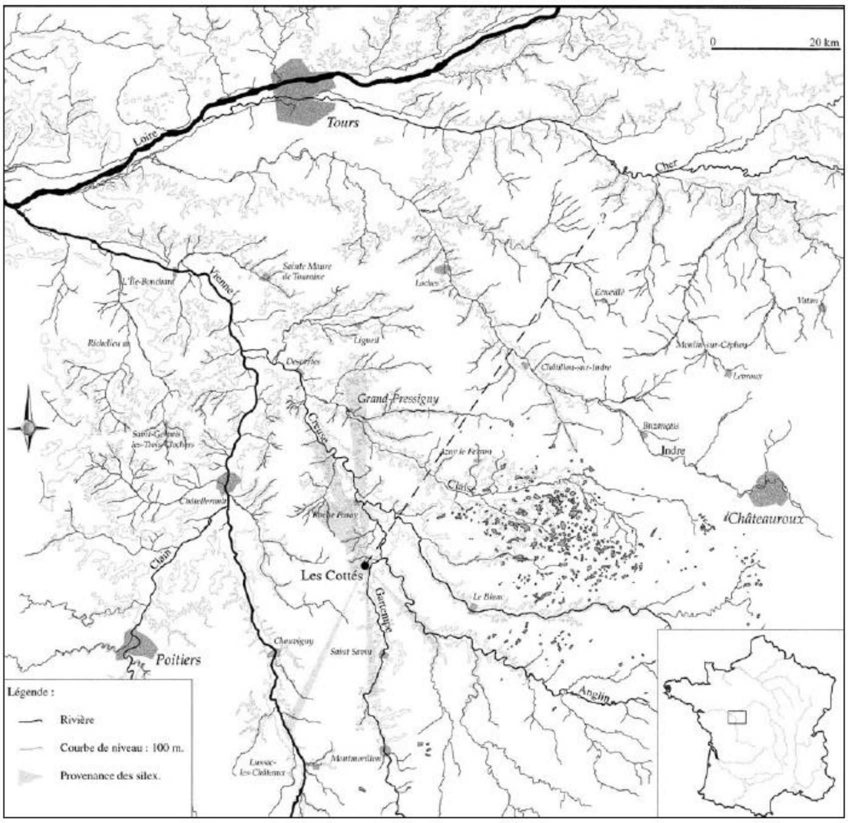


Figure n°134 : Territoire d'approvisionnement en silex, couche 2, Les Cottés, Saint-Pierre-de-Maillé (Vienne).

Figure 54. Sourcing pattern from level C, Les Cottés. Copied Primault 2003, 240 figure 134.

Primault (2003, 238) examined 156 lithic artefacts recovered from Pradel's excavations. The sourcing of this material (Figure **54**) follows a similar regime to that of the underlying Early Aurignacian, level D. Just over 27% of the assemblage was made on local materials while ~60% of the assemblage was made on upper Turonian flint located about 10km to the north of the site (Figure **55**).

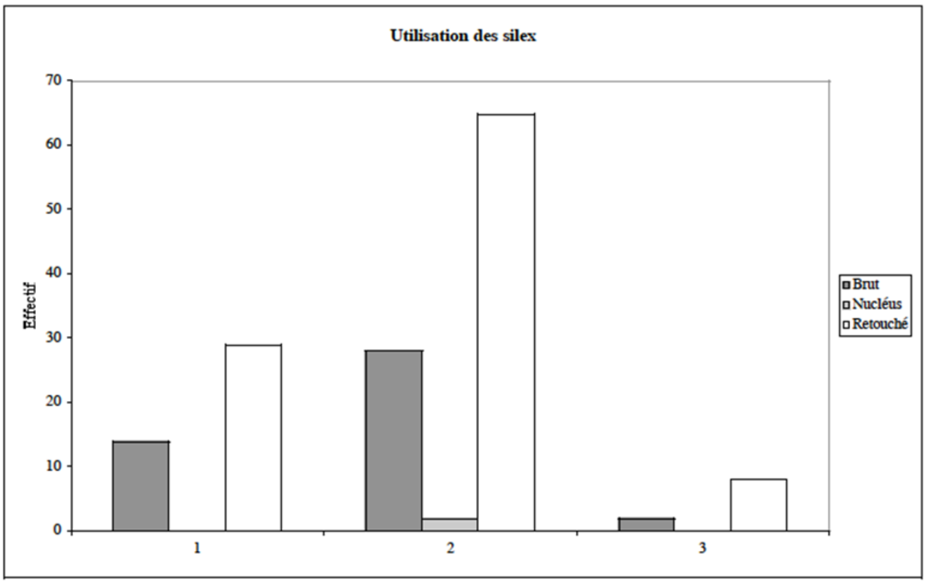


Figure n°135 : Utilisation des silex, couche 2, Les Cottés, Saint-Pierre-de-Maillé (Vienne).
Légende : 1 : silex locaux ; 2 : silex voisins ; 3 : silex exogènes.

Figure 55. Percentages of local, semi-local, and non-local lithic materials from level C, Les Cottés. Copied from Primault 2003, 242 figure 135.

Level D:

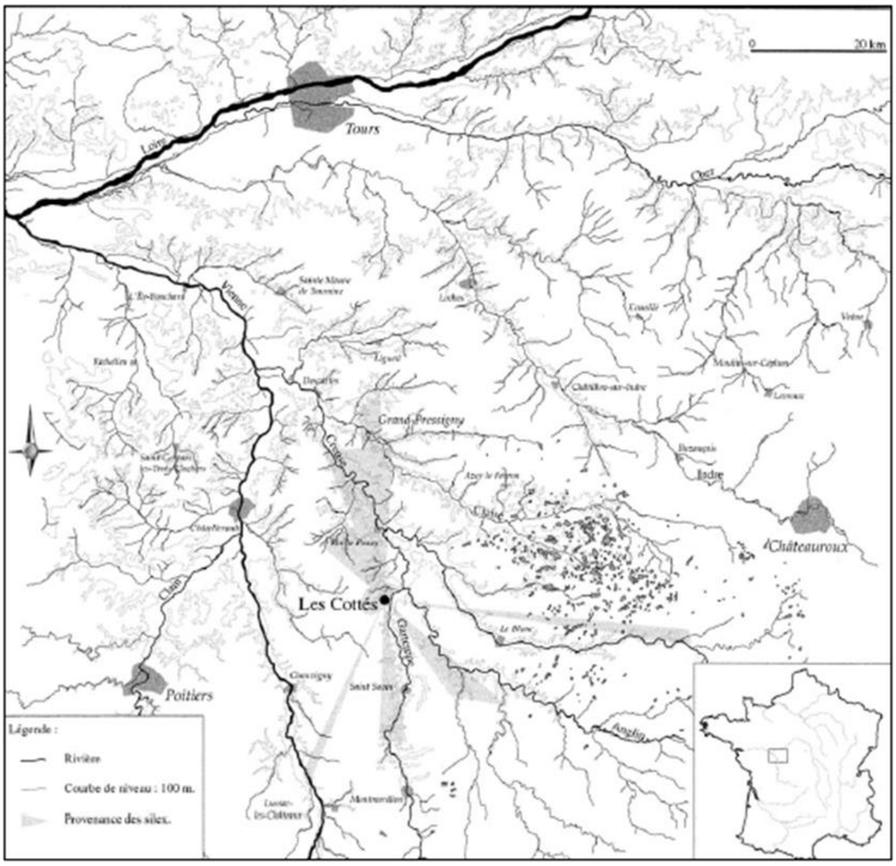


Figure n°110 : Territoire d'approvisionnement en silex, couche E supérieure,
Les Cottés, Saint-Pierre-de-Maillé (Vienne).

Figure 56. Sourcing pattern from level D, Les Cottés. Copied Primault 2003, 204 fig. 110. Primault designates level D as '*couche E supérier*'.

Primault was able to locate and examine 220 elements from Level D (2003, 201). The majority of the material (64.1%) is classified as an upper Turonian flint that is sourced from at least 10km from the site (Primault 2003, 201). Twenty-five percent of the flint is a local brown flint, which is a significant reduction in the use of this material from the underlying assemblages (ibid, 202). Some of the Turonian material can range as far as 25km or more from the site. The remaining material, smaller in number (6.3%), comes mostly from within 50km of the site (ibid, 202). The overall maximum extension of lithic sourcing around Les Cottés (Figure **56**) during the Early Aurignacian from level D results in a radius of 30km to the north and 50km to the east (ibid, 203).

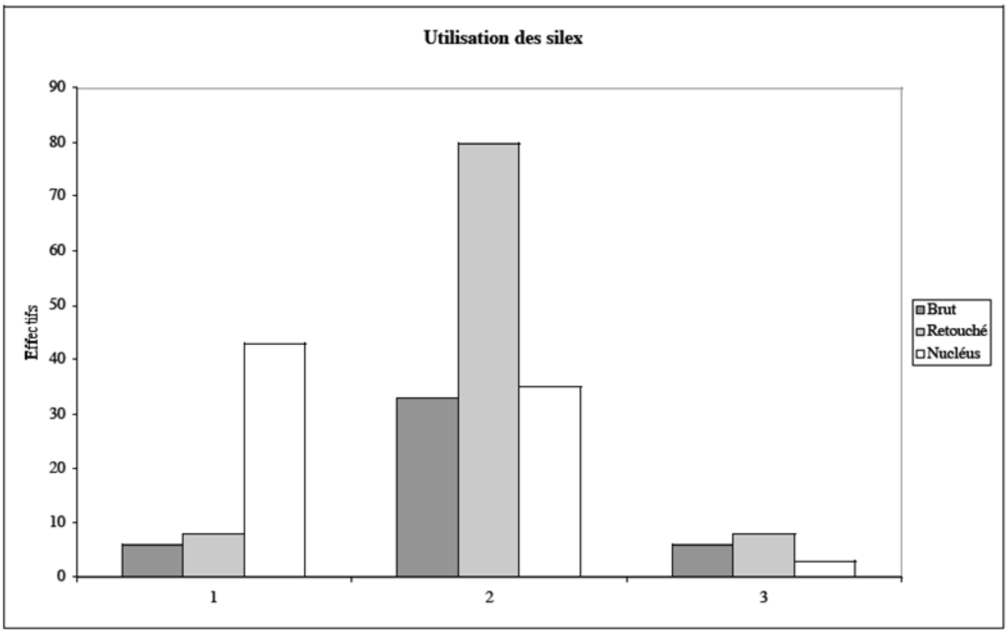


Figure n°111 : Utilisation des silex, couche E supérieure,
Les Cottés, Saint-Pierre-de-Maillé (Vienne).
Légende : 1 : silex locaux ; 2 : silex voisins ; 3 : silex exogènes.

Figure 57. Percentages of local, semi-local, and non-local lithic materials from level D, Les Cottés. Copied from Primault 2003, 206 figure 111.

Tools comprise a large portion of Primault's sample population (n = 96, ~44% of the total sample) (2003, 204). A large component of these tools are scrapers on blades (n = 54) (Ibid, 205). Large blades and blade blanks account for a smaller number (n = 13) (Primault 2003, 210). The presence of large blades may support a functional explanation for the higher presence of non-local material in the lithic assemblages (Figure **57**), as the local, brown, Cottés flint is not suitable for the reduction of large blades. Though this local flint has good conchoidal fracturing properties, it is often found in small nodules (Primault 2003, 193). The large blades themselves must have been or were most likely curated as blanks or formal tools since there is little to no evidence of their onsite reduction (Primault 2003, 211). To this end, the reduction of smaller blades was carried out onsite on the local brown flint (Primault 2003, 208), similar to the underlying Protoaurignacian and Early Aurignacian levels as well as the Chatelperronian.

Level E:

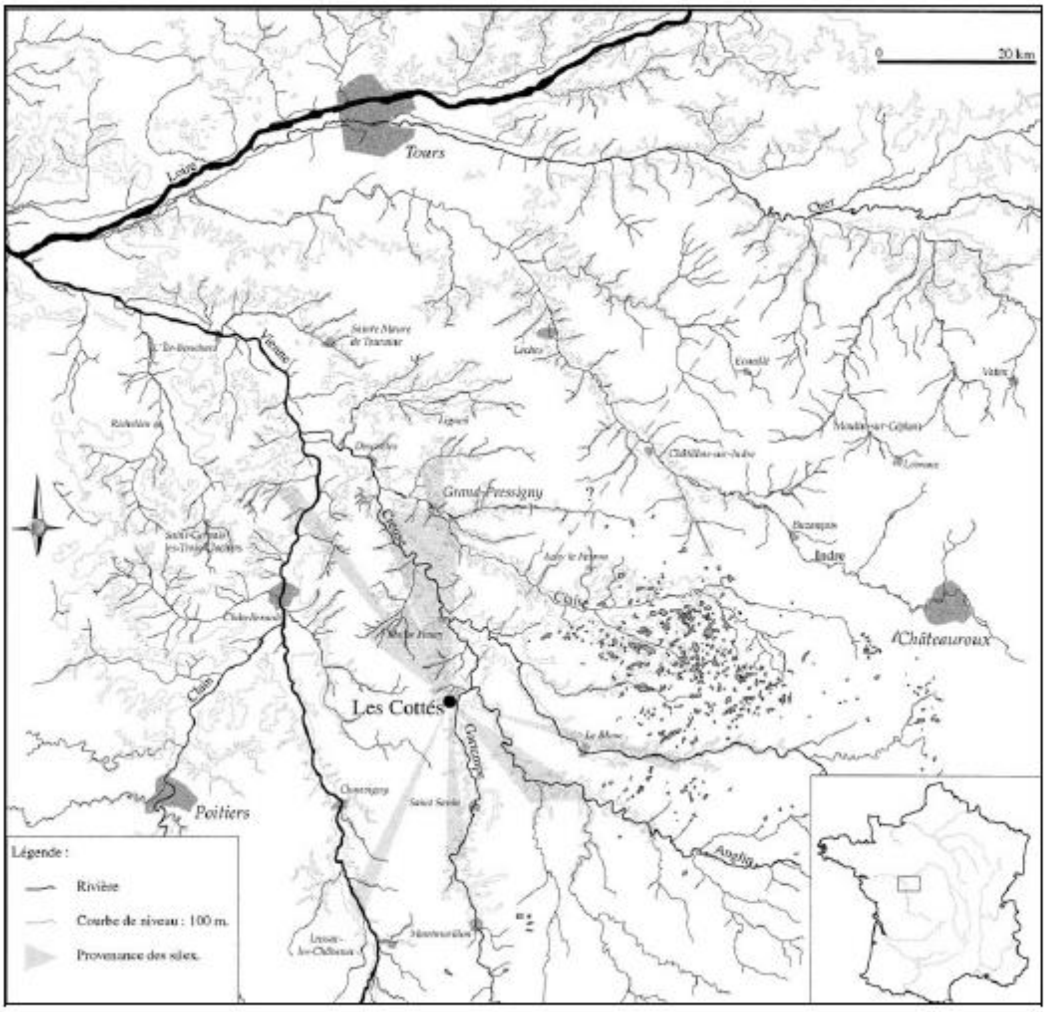


Figure n°104 : Aire de provenance des silex, Aurignacien ancien, Couche E inférieure, Les Cottés, Saint-Pierre-de-Maillé (Vienne).

Figure 58. Sourcing pattern from level E, Les Cottés. Copied Primault 2003, 187 figure 104.

Primault had access to 1426 elements to examine from level E (2003, 184). This collection is a combination of the Protoaurignacian and Early Aurignacian deposits from this level due to Pradel's division of the sequence. This explains in part Primault's (ibid) remarking on the peculiarity of the Aurignacian assemblage from Level E due to the presence of many small prismatic cores and short thin blades struck by direct percussion. Despite this setback, there is some indication of differences between the Protoaurignacian and Early Aurignacian of level E. For example, Soressi et al. (2010, 230) indicate a preference for local material in both levels, but that non-local sources account for a larger portion of the Early Aurignacian assemblage.

Primault (2003, 185) notes that nearly all known flint outcrops within a 30 to 40km radius of the site are represented within the level E assemblage (Figure **58**). This makes the assemblage slightly more diverse than the underlying Chatelperronian (sources for Level E n = 14, level G n = 10). However, the inclusion of a larger number of raw material sources may be a bias of the assemblage size rather than an actual diversification in the sourcing regime (ibid).

Over half of the assemblage (Figure **59**) is comprised of materials collected within a kilometre or less of the site while 49.5% of the assemblage is formed on one local material source, the brown coloured local flint (Primault 2003, 185). This material was also heavily utilized during the Chatelperronian occupation of the site. The second highest exploited material (38.4%), Upper Turonian (ibid), was also the second most utilized material during the Chatelperronian occupation. The highly uniform concoidal fracturing properties of these materials, especially the local brown flint, may explain their dominance in the assemblage. Less than 5% of the materials were collected from sources 20 to 30km from the site. This follows a similar pattern seen during the Mousterian occupation while the sourcing distances of non-local materials indicate a pattern similar to that of the underlying Chatelperronian. However, like level D, large blades are constructed on Upper Turonian flint located about 10km to the north of the site (Primault 2003, 193). Primault (2003, 186) notes a further two flakes that may have been struck from material 50km from the site, and one blade fragment with cortex that may have been made on material sourced 60km or perhaps even 80km to the north.

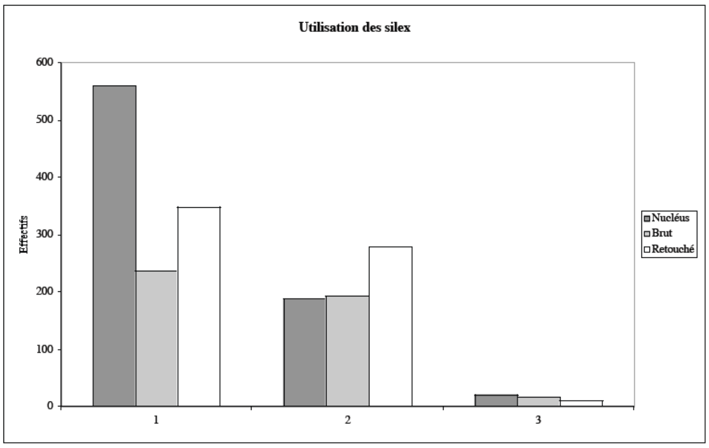


Figure n°106 : Utilisation des silex, couche E inférieure,
Les Cottés, Saint-Pierre-de-Maillé (Vienne).
Légende : 1 : silex locaux ; 2 : silex voisins ; 3 : silex exogènes.

Figure 59. Percentages of local, semi-local, and non-local lithic materials from level D, Les Cottés. Copied from Primault 2003, 191 fig. 106.

Level G:

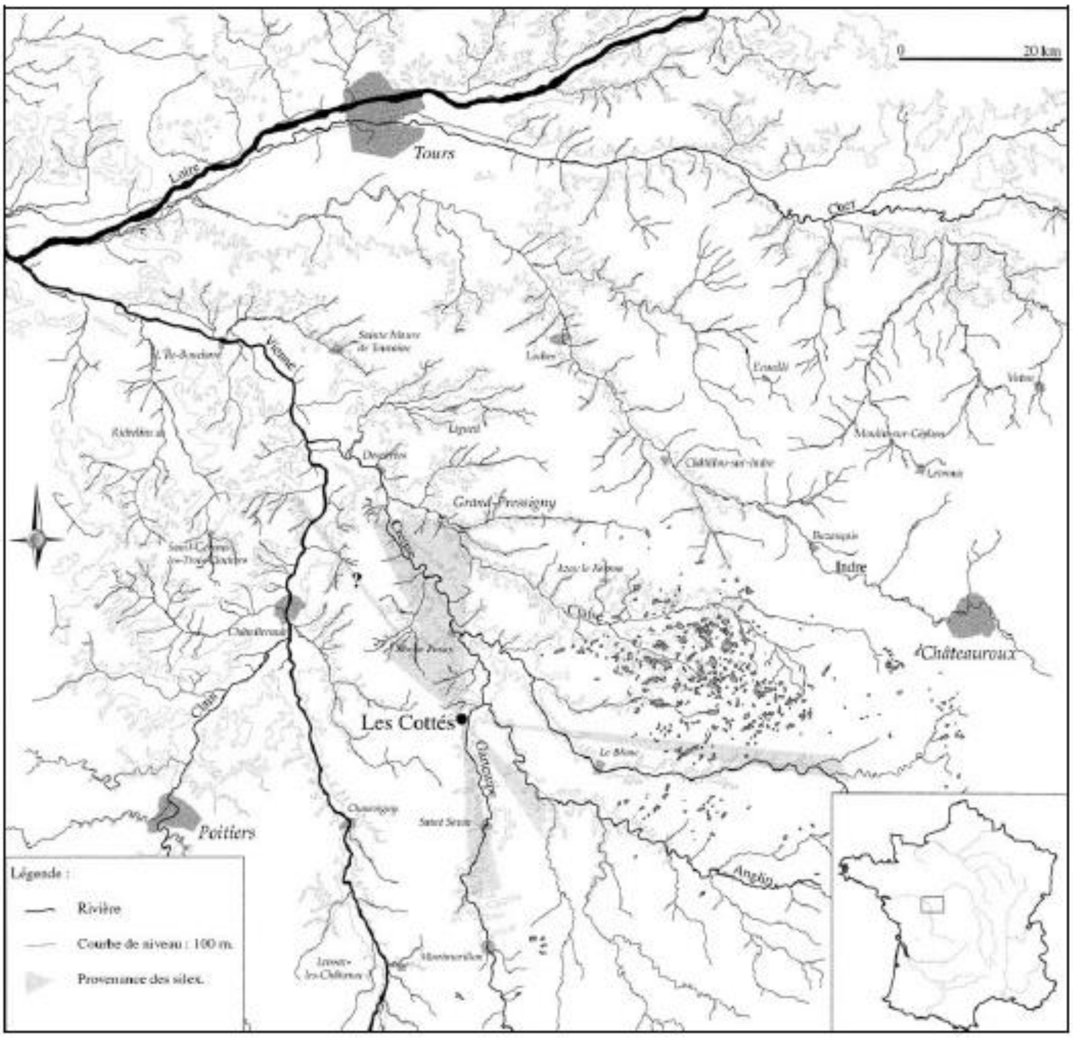


Figure n°95 : Territoire de provenance des silex,
couche G, Les Cottés, Saint-Pierre-de-Maillé (Vienne).

Figure 60. Sourcing pattern from level G, Les Cottés. Copied Primault 2003, 168 fig. 95.

Primault was only able to examine 347 lithic elements from Pradel's excavations. This is surprisingly small, given that Pradel (1961) records 552 tools from level G. The difference in size is most likely a result of the assemblage being divided and curated at various locations (Primault 2003, 166), resulting in the unfortunate loss or misplacement of some of the original assemblage.

The sourcing of lithic material follows a local pattern like the overlying level E (Figure **60**). Ten different types of flint were utilized during the Chatelperronian occupation (Primault 2003, 167 fig. 94). Most of the flint was sourced from a distance no greater than 10km to the north of the site, and overall, the assemblage is composed of ~56% local material (Figure **61**). However, there are some elements that have longer transport distances. For example, there are some elements made of Bathoniens flint, which can be found about 50km to the east of Les Cottés (Primault 2003, 166-7). There is also a blade fragment on Fontmaure jasper with a provenance some 30km to the northwest.

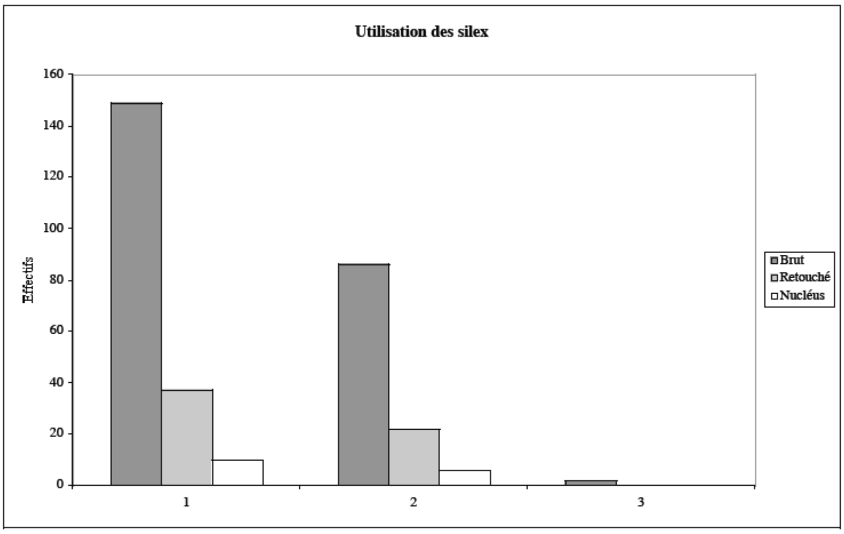


Figure n°98 : Utilisation des silex, couche G, Les Cottés, Saint-Pierre-de-Maillé (Vienne).
Légende : 1 : silex locaux ; 2 : silex voisins ; 3 : silex exogènes.

Figure 61. Percentages of local, semi-local, and non-local lithic materials from level G, Les Cottés. Copied from Primault 2003, 171 fig. 98.

Level I:

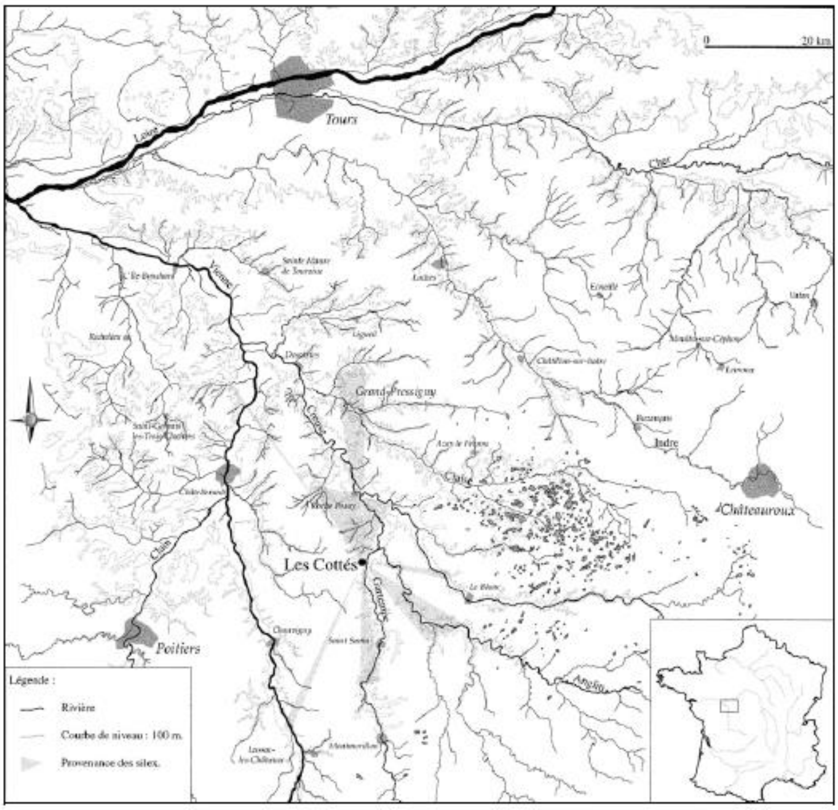


Figure n°77 : Territoire de provenance des silex,
Couche 6, les Cottés, Saint-Pierre-de-Maillé (Vienne).

Figure 62. Sourcing pattern from level I, Les Cottés. Copied Primault 2003, 141 fig. 77.

Primault (2003, 139) was able to ascertain the provenance of most of the lithic material. The assemblage is composed of 14 different types of flint (Primault, 2003, 140 fig. 76). However, the material is assumed to be mostly local in origin within about a kilometre of the site. In fact, the known provenance of the sourced material occurs largely within a 10-20 km radius (Figure **62**). However, there are a limited number of materials that fall beyond this range, which deserve further consideration.

While ~60% of the material is represented by the local brown flint, a small portion (n = 62, ~8%) of the material is intermediate or non-local in origin, i.e. >20km (Figure **63**). This material is present at the site in the form of flakes and retouched tools (Primault 2003, 142 fig. 78). Thirty-nine elements were probably sourced from the Creuse Valley slightly greater than 20km from the site. Interestingly, 9 elements were sourced from 30km to the South, 13 were sourced from 30km to the northeast, and 1 flake was sourced from about 30km to the northwest of the site, demonstrating diameter of circulation/sourcing around Les Cottés of ≥60km.

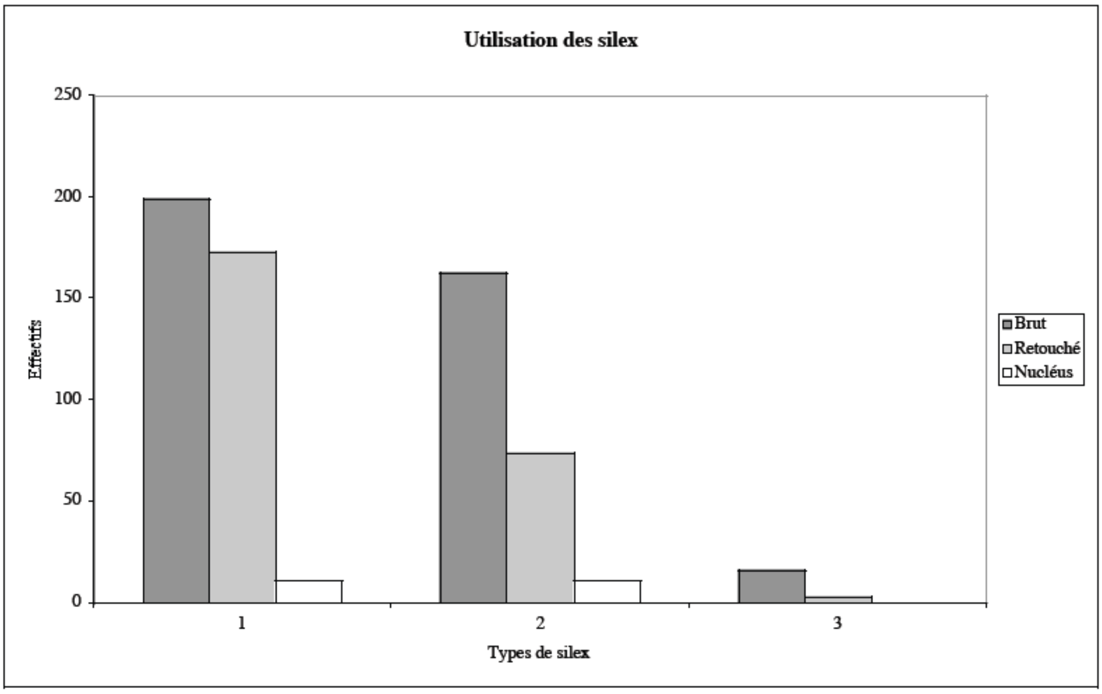


Figure n°78 : Utilisation des silex, couche 6, les Cottés, Saint-Pierre-de-Maillé (Vienne).
Légende : 1 : silex locaux ; 2 : silex voisins ; 3 : silex exogènes.

Figure 63. Percentages of local, semi-local, and non-local lithic materials from level I, Les Cottés. Copied from Primault 2003, 142 fig. 78.

Synthesis

1. Local flint sources progressively decrease from the Mousterian to the final Aurignacian level: Mousterian ~62%, Chatelperronian ~57%, Aurignacian level E 52.9%, Early Aurignacian 25.9%.

2. Though local sources decrease through the Middle to Upper Palaeolithic transition, materials beyond 20km play only a small role both before and after the transition.

3. Even though long distance materials are represented in each assemblage, Primault does not see them as products of trade or direct procurement, especially during the Chatelperronian (Primault 2003, 167), but rather long distance movement of individuals.

Faunal Evidence

Thorough descriptions of the faunal assemblage from Les Cottés are limited, and an analysis of the final archaeological level, C, has never been published. Since Bouchud

(1961) first examined materials from Pradel's excavations, faunal analysis has largely been directed at palaeoclimatic palaeoecological reconstructions rather than assessing the subsistence behaviour of the site's past occupants. The current research team will rectify this issue, but such a publication is still forthcoming (Rendu *pers. comm.*). For his part, Bouchud (1961) observed a progressive increase in reindeer from the Mousterian to the Aurignacian, which he interpreted as suggesting a cooling and opening of the surrounding environment.

Fouin et al. (2013), using materials from recent excavations, have generally upheld Bouchud's interpretation. To this same end, they note that the Les Cottés faunal pattern agrees with MIS3-2 Dordogne environmental synthesis proposed by Discamps et al. (2011). In brief, there was a linear increase in reindeer at the end of MIS3 to the detriment of equids and bovids culminating in H4 when reindeer almost completely dominate the landscape. This trend is mirrored in Les Cottés sequence. Throughout the sequence, the same three fauna are predominant, *R. tarandus*, *Equus*, and *Bos*, representing at least 89% of the material in the faunal assemblages.

Level D:

Reindeer are by far the most dominant species in this level, composing 97% of the assemblage (Welker et al. 2015, 280 table 1). Equids follow at great distance with 1.4% followed closely by bovids with 1% (ibid). Compared to the underlying levels, the significant increase in reindeer may reflect a rapid cooling of an increasingly more open environment. Alternatively, the small size of the material cultural assemblage may suggest that the accumulation of the faunal assemblage was the result of more limited activities at the site such as a singular hunting episode directed at the exploitation of a reindeer herd as it moved past the cave itself. However, the underlying assemblages, regardless of their size, point to a linear increase in the proportion of reindeer. Therefore, the nonspecific nature of the assemblage is more likely a result of environmental conditions rather than human selection.

Level E:

The faunal assemblage is noted as reflecting a more arctic spectrum than the underlying level G. In fact, it is within level E itself (i.e. between upper and lower unit 04) that temperate species give way to arctic ones (Frouin et al. 2013, 193).

-Unit 04 (Upper)
Reindeer account for 88% of the assemblage. Equids count for 8% of the assemblage while *Bos* only make up 2%. (Welker et al. 2015, 280 table 1)

-Unit 04 (Lower)
Reindeer represent 68% of the total assemblage. Equids comprise 23% of the assemblage while *Bos* only account for 6 (ibid).

Shifts in the faunal distribution between lower and upper unit 04 presage the arctic conditions of level D. This continues a trend already established in the underlying assemblages. At the same time, the absence of carnivore surface modification (Soressi et al. 2010; Talamo et al. 2012; Welker et al. 2015) sets level E apart from levels G and I. Despite this, level E contains the only assemblage throughout the entire sequence representing more than one type of carnivore, *Canidae* and *Hyaenidae* (Welker et al. 2015, 280 table 1).

Level G:

Pradel (1959, 425) notes that the fauna assemblage recovered from level G is comprised of steppic species suited to a very cold climate. The dominant species is reindeer (Soressi et al. 2010, 230), accounting for ~51% of the assemblage (Welker et al. 2015, 280 table 1). Bovids are the next most common at ~25%; interestingly, level G is the least abundant in equids compared to the rest of the sequence, composing 1% of the assemblage (ibid). Though there is a reduction in carnivore surface modification compared level I, the relative presence of carnivore skeletal remains is the highest out of the entire sequence, 7% (ibid).

Level I:

Reindeer are the dominant species in the assemblage, ~45%. However, this makes level I the least reindeer dominant assemblage out of the sequence. Bovids follow at 36% while equids comprise ~16%, making this level the second most common in horses. (Welker et al. 2015, 280 table 1)

Bovids and horses account for just over half of the faunal assemblage (Welker et al. 2015, 280). The high percentage of these species suggests a more steppic environment (Frouin et al. 2013, 193) compared to the other assemblages. The frequency of surface modification by carnivores also sets this level apart from superseding levels, especially the Aurignacian horizon (Soressi et al. 2010).

Carnivore activity:

Humans were not the only agent of faunal accumulation at the site. There is ample evidence for the presence of carnivores such as surface modification, gnawing marks and etching from digestive acids, on faunal elements as well as physical remains of carnivores themselves. It has been argued that evidence for carnivore activities decreases through the sequence (Soressi et al. 2010; Talamo et al 2012). To this end, reductions in surface modification suggest that carnivores contributed significantly less to the Aurignacian assemblages than to the Mousterian and Chatelperronian ones (Soressi et al, 2010; Talamo et al. 2012; Welker et al. 2015). However, this stands at odds with the physical presence throughout the stratigraphic sequence of hyenoid and canid skeletal remains.

Analysis of faunal assemblages from both Pradel's excavations and Soressi's recent excavations confirm the presence of carnivore remains (Bouchud 1961; Welker et al. 2015). For his part, Bouchard (1961), recorded carnivore skeletal elements from the Mousterian to the final Aurignacian level, and though carnivore species vary, he did not observe a reduction in their presence within the Aurignacian assemblages. Analysis of excavated materials since 2006, demonstrate the presence of carnivore remains both the Protoaurignacian and Early Aurignacian assemblages from level E (Welker et al. 280 table 1). Nevertheless, carnivore surface modification on the rest of the assemblage is negligible to non-existent in this level (Soressi et al. 2010). Given that the Mousterian level I has the greatest percentage of carnivore surface modification (15.5%) (Talamo et al. 2012, 178) coupled with the small size of the level's lithic assemblage (n = 350), occupation intensity may account for the variances in the evidence of carnivore activities throughout the sequence.

However, occupation intensity is actually a poor explanation. For example, lower unit 04, while possessing the largest lithic assemblage (n = 6466), has the same relative percentage of carnivore remains as level I. Further, the near overlap in dating results from the Protoaurignacian and Early Aurignacian of level E along with skeletal evidence for two different types of denning carnivores may suggest significant bioturbation during an otherwise highpoint in the human occupation of Les Cottés. Given these concerns, the degree to which carnivores contributed to the accumulation of faunal remains both before and after the Middle to Upper Palaeolithic transition at Les Cottés is yet to be resolved.

Synthesis:

1. The trend in the pattern of fauna suggests a progressive cooling and opening of the landscape as suggested by Bouchud (1961).

2. The Mousterian level I, accumulating before the onset of the Les Cottés interstadial, has a faunal pattern suggestive of a steppic environment. As such, the dominance of reindeer and presence of horse indicate a cool and open environment.

3. The increase in reindeer coupled with a decrease in bison and major reduction in equids indicates a significant cooling during the Chatelperronian occupation of the site, level G. The environment may therefore have been too cold and inhospitable to sustain stable horse populations.

4. During the Protoaurignacian occupation of the site, lower level E, the environment may have become more arid as suggested by the increase in percentage of reindeer and major decrease in bovids. At the same time, the environment may have become slightly warmer as indicated by an increase in the percentage of horse.

5. The first Early Aurignacian occupation, upper level E, most likely occurred during an increasingly cold and arid period as demonstrated by the decrease in horse and bovids coupled with increase in reindeer.

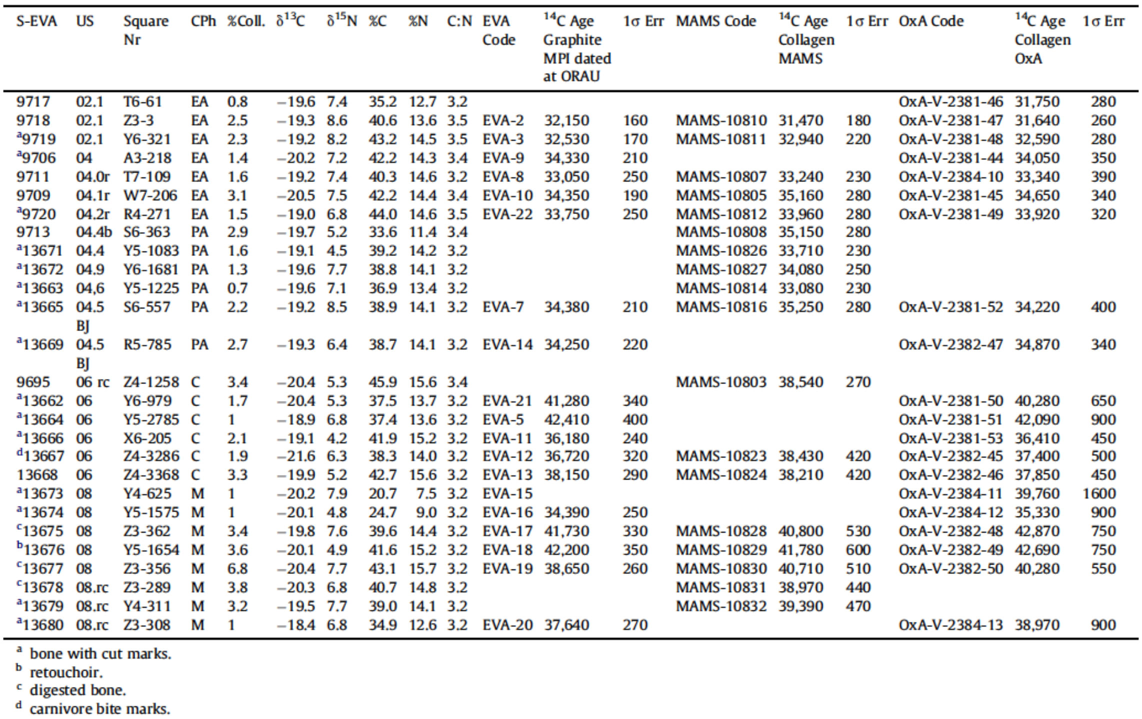
6. The final Early Aurignacian occupation, level D, coincides with a tundra-like environment. Equids are nearly absent and so are bovids. Reindeer are overwhelming the most dominant species.

7. The complex nature of the evidence for carnivore activities at the site needs further consideration. Until this is done, the question of whether humans or carnivores contributed more or less during different occupation periods of the site will remain open-ended.

Site Chronology

To date, radiocarbon testing has been the most comprehensive chronometric method used at Les Cottés. Under the direction of Pradel, traditional radiocarbon testing was conducted on the cultural levels at Les Cottés. According to Talamo et al. (2012, 176 table 1), the traditional radiocarbon results yielded several dates for the archaeological horizons in accordance with Pradel's divisions: a mean of 23,420RCY for the Gravettian, 30,800, 31,200, and 31,000RCY for the early Aurignacian, 33,300 and 31,900RCY for the Chatelperronian, and 32,300 and 37,600RCY for the Mousterian.

A new dating program (Talamo et al. 2012) was undertaken by the current excavation team to retest the traditional radiocarbon results as well as to provide a chronology for the revised archaeological sequence. The purview of the published data that has come out of this new program is limited to the *transitional* assemblages: Mousterian, Chatelperronian, Protoaurignacian, and Aurignacian levels. Though refitting analysis appears to confirm the individual identity of the Protoaurignacian and Early Aurignacian assemblages contained in level E (unit 04) (Soressi et al. 2010), the two levels could not be distinguished using the radiocarbon method (Talamo et al. 2012). All samples were subject to ultrafiltration and to the AMS radiocarbon dating method and were tested by three different laboratories, the Oxford Radiocarbon Laboratory, the Mannheim AMS Laboratory, and the MPI-EVA Laboratory (Table **25**). The Oxford and Mannheim laboratories both utilized collagen while MPI-EVA utilized graphite to date the Les Cottés samples.



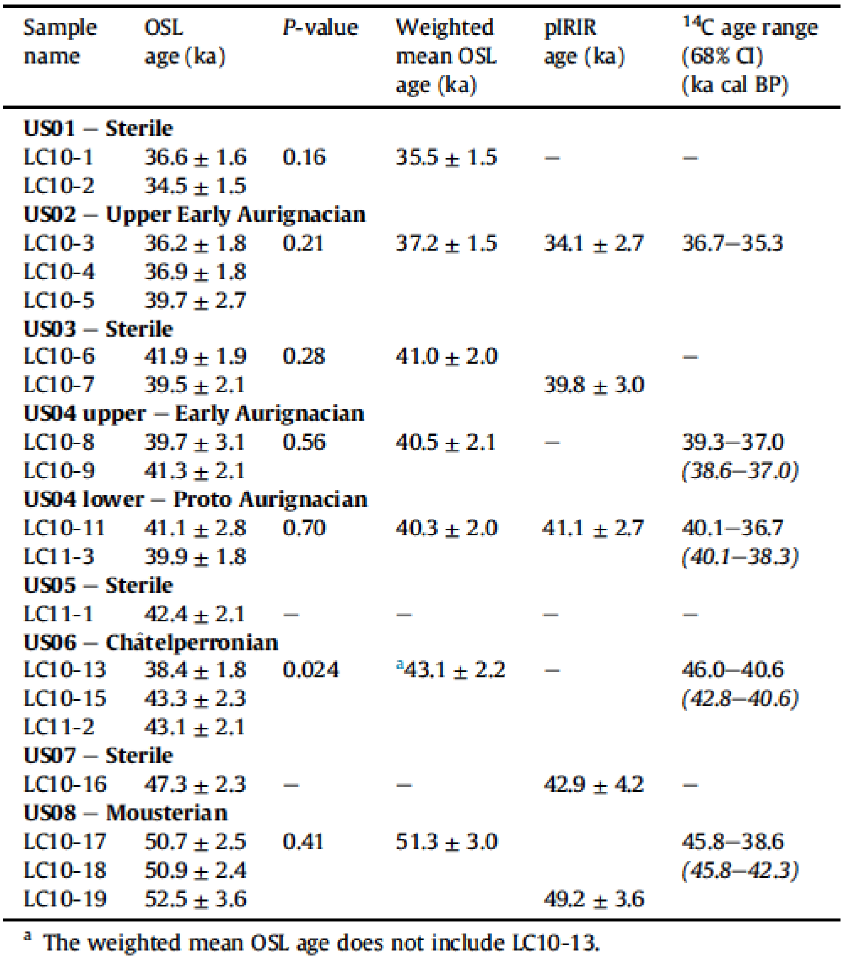
S-EVA	US	Square Nr	CPh	%Coll.	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C:N	EVA Code	^{14}C Age Graphite MPI dated at ORAU	1σ Err	MAMS Code	^{14}C Age Collagen MAMS	1σ Err	OxA Code	^{14}C Age Collagen OxA	1σ Err
9717	02.1	T6-61	EA	0.8	−19.6	7.4	35.2	12.7	3.2							OxA-V-2381-46	31,750	280
9718	02.1	Z3-3	EA	2.5	−19.3	8.6	40.6	13.6	3.5	EVA-2	32,150	160	MAMS-10810	31,470	180	OxA-V-2381-47	31,640	260
[a]9719	02.1	Y6-321	EA	2.3	−19.2	8.2	43.2	14.5	3.5	EVA-3	32,530	170	MAMS-10811	32,940	220	OxA-V-2381-48	32,590	280
[a]9706	04	A3-218	EA	1.4	−20.2	7.2	42.2	14.3	3.4	EVA-9	34,330	210				OxA-V-2381-44	34,050	350
9711	04.0r	T7-109	EA	1.6	−19.2	7.4	40.3	14.6	3.2	EVA-8	33,050	250	MAMS-10807	33,240	230	OxA-V-2384-10	33,340	390
9709	04.1r	W7-206	EA	3.1	−20.5	7.5	42.2	14.4	3.4	EVA-10	34,350	190	MAMS-10805	35,160	280	OxA-V-2381-45	34,650	340
[a]9720	04.2r	R4-271	EA	1.5	−19.0	6.8	44.0	14.6	3.5	EVA-22	33,750	250	MAMS-10812	33,960	280	OxA-V-2381-49	33,920	320
9713	04.4b	S6-363	PA	2.9	−19.7	5.2	33.6	11.4	3.4				MAMS-10808	35,150	280			
[a]13671	04.4	Y5-1083	PA	1.6	−19.1	4.5	39.2	14.2	3.2				MAMS-10826	33,710	230			
[a]13672	04.9	Y6-1681	PA	1.3	−19.6	7.7	38.8	14.1	3.2				MAMS-10827	34,080	250			
[a]13663	04,6	Y5-1225	PA	0.7	−19.6	7.1	36.9	13.4	3.2				MAMS-10814	33,080	230			
[a]13665	04.5 BJ	S6-557	PA	2.2	−19.2	8.5	38.9	14.1	3.2	EVA-7	34,380	210	MAMS-10816	35,250	280	OxA-V-2381-52	34,220	400
[a]13669	04.5 BJ	R5-785	PA	2.7	−19.3	6.4	38.7	14.1	3.2	EVA-14	34,250	220				OxA-V-2382-47	34,870	340
9695	06 rc	Z4-1258	C	3.4	−20.4	5.3	45.9	15.6	3.4				MAMS-10803	38,540	270			
[a]13662	06	Y6-979	C	1.7	−20.4	5.3	37.5	13.7	3.2	EVA-21	41,280	340				OxA-V-2381-50	40,280	650
[a]13664	06	Y5-2785	C	1	−18.9	6.8	37.4	13.6	3.2	EVA-5	42,410	400				OxA-V-2381-51	42,090	900
[a]13666	06	X6-205	C	2.1	−19.1	4.2	41.9	15.2	3.2	EVA-11	36,180	240				OxA-V-2381-53	36,410	450
[d]13667	06	Z4-3286	C	1.9	−21.6	6.3	38.3	14.0	3.2	EVA-12	36,720	320	MAMS-10823	38,430	420	OxA-V-2382-45	37,400	500
13668	06	Z4-3368	C	3.3	−19.9	5.2	42.7	15.6	3.2	EVA-13	38,150	290	MAMS-10824	38,210	420	OxA-V-2382-46	37,850	450
[a]13673	08	Y4-625	M	1	−20.2	7.9	20.7	7.5	3.2	EVA-15						OxA-V-2384-11	39,760	1600
[a]13674	08	Y5-1575	M	1	−20.1	4.8	24.7	9.0	3.2	EVA-16	34,390	250				OxA-V-2384-12	35,330	900
[c]13675	08	Z3-362	M	3.4	−19.8	7.6	39.6	14.4	3.2	EVA-17	41,730	330	MAMS-10828	40,800	530	OxA-V-2382-48	42,870	750
[b]13676	08	Y5-1654	M	3.6	−20.1	4.9	41.6	15.2	3.2	EVA-18	42,200	350	MAMS-10829	41,780	600	OxA-V-2382-49	42,690	750
[c]13677	08	Z3-356	M	6.8	−20.4	7.7	43.1	15.7	3.2	EVA-19	38,650	260	MAMS-10830	40,710	510	OxA-V-2382-50	40,280	550
[c]13678	08.rc	Z3-289	M	3.8	−20.3	6.8	40.7	14.8	3.2				MAMS-10831	38,970	440			
[a]13679	08.rc	Y4-311	M	3.2	−19.5	7.7	39.0	14.1	3.2				MAMS-10832	39,390	470			
[a]13680	08.rc	Z3-308	M	1	−18.4	6.8	34.9	12.6	3.2	EVA-20	37,640	270				OxA-V-2384-13	38,970	900

[a] bone with cut marks.
[b] retouchoir.
[c] digested bone.
[d] carnivore bite marks.

Table 25 Recent radiocarbon results from Les Cottés. Copied from Talamo et al. 2012, 178 table 3.

Consideration was given in the selection of dating materials in order to assess the chronology of the human occupation horizons as well as the potential for stratigraphic mixing or disturbance. In order to accomplish these objectives, anthropically modified bones, carnivore modified bones and unmodified bones were selected from newly excavated test units. The most significant finding of the new dating program is that each archaeological horizon proved be older by “500-5000 radiocarbon years” than previously assumed (Talamo et al. 2012, 180).

Though radiocarbon analysis has been the most comprehensive chronometric method used at Les Cottés, in 2013, Li et al. (2013) published preliminary test results using optically stimulated luminescence. Final publication of the OSL results were released in 2015 by Jacobs et al. The OSL results (Table **26**) are largely in agreement (this is discussed in further detail later on) with the recent radiocarbon analysis.



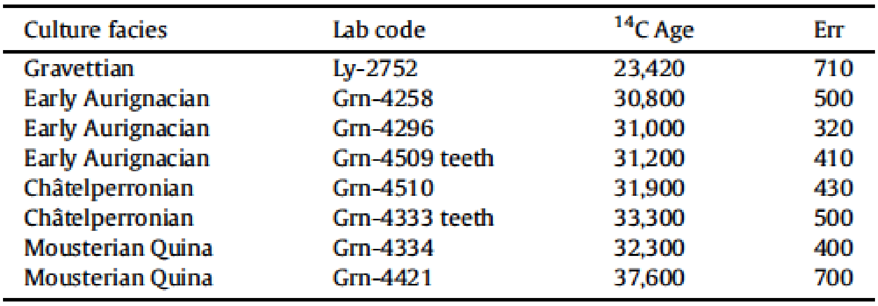
Sample name	OSL age (ka)	*P*-value	Weighted mean OSL age (ka)	pIRIR age (ka)	^{14}C age range (68% CI) (ka cal BP)
US01 – Sterile					
LC10-1	36.6 ± 1.6	0.16	35.5 ± 1.5	–	–
LC10-2	34.5 ± 1.5				
US02 – Upper Early Aurignacian					
LC10-3	36.2 ± 1.8	0.21	37.2 ± 1.5	34.1 ± 2.7	36.7–35.3
LC10-4	36.9 ± 1.8				
LC10-5	39.7 ± 2.7				
US03 – Sterile					
LC10-6	41.9 ± 1.9	0.28	41.0 ± 2.0		–
LC10-7	39.5 ± 2.1			39.8 ± 3.0	
US04 upper – Early Aurignacian					
LC10-8	39.7 ± 3.1	0.56	40.5 ± 2.1	–	39.3–37.0
LC10-9	41.3 ± 2.1				*(38.6–37.0)*
US04 lower – Proto Aurignacian					
LC10-11	41.1 ± 2.8	0.70	40.3 ± 2.0	41.1 ± 2.7	40.1–36.7
LC11-3	39.9 ± 1.8				*(40.1–38.3)*
US05 – Sterile					
LC11-1	42.4 ± 2.1	–	–	–	–
US06 – Châtelperronian					
LC10-13	38.4 ± 1.8	0.024	[a]43.1 ± 2.2	–	46.0–40.6
LC10-15	43.3 ± 2.3				*(42.8–40.6)*
LC11-2	43.1 ± 2.1				
US07 – Sterile					
LC10-16	47.3 ± 2.3	–	–	42.9 ± 4.2	–
US08 – Mousterian					
LC10-17	50.7 ± 2.5	0.41	51.3 ± 3.0		45.8–38.6
LC10-18	50.9 ± 2.4				*(45.8–42.3)*
LC10-19	52.5 ± 3.6			49.2 ± 3.6	

[a] The weighted mean OSL age does not include LC10-13.

Table 26. OSL dating results from Les Cottés. Copied from Jacobs et al. 2015, 114 table 2.

Findings and discrepancies of the latest radiocarbon results:

According to Talamo et al., "OxCal [found] no agreement between [their] full set of dates and stratigraphy" (2012, 180). It took the removal of eight of the dates from their dataset (~30% of the total dated samples) to enable an "82%" agreement with the site stratigraphy. The previous dating attempts (Table **27**) also suggest a potential chronostratigraphic problem, as the youngest date for the Mousterian is a thousand years younger than the oldest date for the Chatelperronian.



Culture facies	Lab code	^{14}C Age	Err
Gravettian	Ly-2752	23,420	710
Early Aurignacian	Grn-4258	30,800	500
Early Aurignacian	Grn-4296	31,000	320
Early Aurignacian	Grn-4509 teeth	31,200	410
Châtelperronian	Grn-4510	31,900	430
Châtelperronian	Grn-4333 teeth	33,300	500
Mousterian Quina	Grn-4334	32,300	400
Mousterian Quina	Grn-4421	37,600	700

Table 27. Traditional radiocarbon results from Les Cottés. Copied from Talamo et al. 2012, 176 table 1.

A look at all of the radiocarbon results (Figure **64**) questions the stratigraphic security of the site. The polynomial relationship of the sample ages and the site stratigraphy is low ($R^2 = 0.77$) given what should be a fairly direct relationship between superimposed strata and their age under such a model. Two factors may have contributed to this problem, ancient anthropic disturbance and possible bioturbation (such as hyena denning). Though such scenarios would contradict geoarchaeological observations (Pradel 1959, Lévêque 1997, Talamo et al. 2012) the low association of radiocarbon results derived from carnivore modified samples ($R^2 = 0.57$) and anthropically modified samples ($R^2 = 0.63$) leaves little room for alternative interpretation.

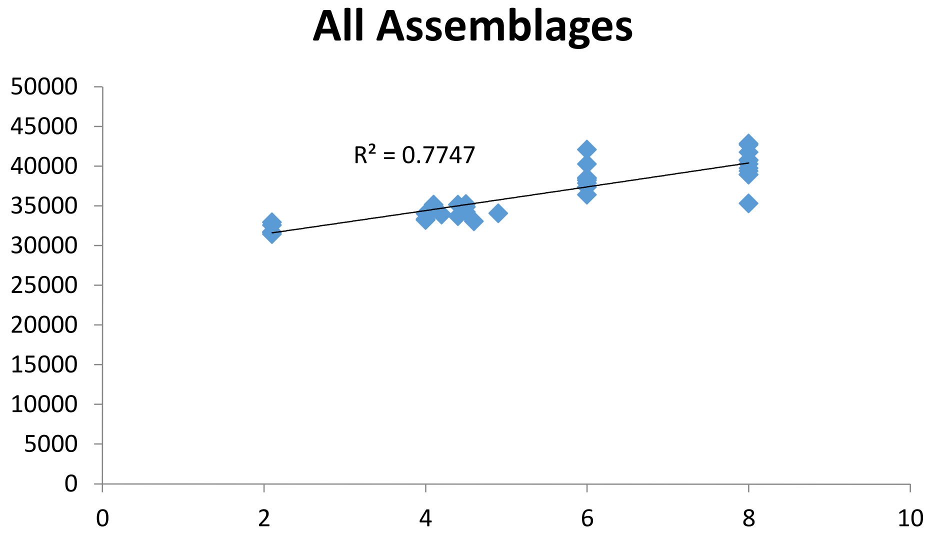


Figure 64. Polynomial relationship of the recent radiocarbon results and the site stratigraphy from Les Cottés.

There is a high correlation between the dating results from the unmodified samples and stratigraphic elevation ($r^2 = 0.96$), which adds to the assumption that ancient human and carnivore activities may have disturbed the linear formation of the stratigraphy. However, two caveats must be considered: there were no samples from the Mousterian horizon, level I, that were unmodified, and the deposition of the unmodified samples was not necessarily independent of human or carnivore activity. With the above discussion in mind, looking at differences between the dating results from Oxford and Mannheim (both laboratories utilized collagen in the dating methods) is warranted.

-Reassessing the new radiocarbon results

Repeated observation (Pradel 1959, 1961, Lévêque 1997, Talamo et al. 2012) has demonstrated the superposition of the archaeological horizons as well as presence of sterile levels between the Mousterian and Chatelperronian as well as between the

Chatelperronian and first Aurignacian horizon. Despite this, both the standard radiocarbon and ultrafiltrated AMS radiocarbon results suggest a degree of stratigraphic mixing or disturbance. The selective process used by Talamo et al. (2012) to rectify these chronostratigraphic issues was highly reliant on the Oxcal and IntCal built-in modelling programs. Perhaps a simpler modelling process, one that judges the fitness of individual samples in relation to the internal consistencies of the sample population itself (e.g. Verpoorte 2005; Graf 2008 153-160), might be more parsimonious. To this end, the difference in dating results from the same samples between the Oxford and Mannheim laboratories (both utilized bone collagen whereas MPI-EVA uses graphite) deserves special consideration in any attempt to rectify the noted chronostratigraphic issues.

The chronology laid out in Table **28** is then proposed based on a simple set of criteria: only definitively anthropic samples are used for the Mousterian and Chatelperronian due to the possibility of ancient mixing or movement of material within each associated stratigraphic horizon, the Mousterian averaged mean is assumed at weighted mean +1 σ, and the samples for the Chatelperronian and Aurignacian horizons that produced results from Mannheim and Oxford with a difference approaching or surpassing 1,000RCY have been removed.

Anthropogenics	Technocomplex	SD	+1 σ	Average
	Mousterian			**(42067.5)**
bone retoucher	41780	600	42380	
bone retoucher	42690	750	43440	
cut mark	39390	470	39860	
cut mark	38970	900	39870	
	Chatelperronian			**39593.3**
cut mark	40280	650		
cut mark	42090	900		
cut mark	36410	450		
	Aurignacian			**34100.8**
N/A	34050	350		
N/A	33340	390		
N/A	33240	230		
N/A	35160	280		

Table continued

N/A	34650	340
N/A	33960	280
N/A	33920	320
N/A	35150	280
N/A	33710	230
N/A	34080	250
N/A	33080	230
N/A	34870	340

Table 28. Modified list of radiocarbon results from Les Cottés according the criteria proposed in this chapter.

The proposed chronology presents a good fit with the site stratigraphy (R^2= 0.96 polynomial regression). This seems to imply the residues of the Mousterian and perhaps the Chatelperronian occupations of the site may be slightly older than the average age of their surrounding matrices. This should not be too surprising as the observation that Chatelperronian and Mousterian lithic assemblages show some signs of patina, indicating a degree of surface exposure prior to deposition through typical soil formation. Further, the greater presence of carnivore remains from these levels leaves open the possibility of ancient bioturbation.

Dating the Mousterian occupation of the nearby site of Les Rocher-de-Villeneuve posed similar issues. A stratigraphic level (level J) containing a Neanderthal femur had previously been dated to ~40,000RCY (Beauval et al. 2005). This level contains a similar pattern of artefactual and faunal assemblages to that of the Mousterian level at Les Cottés (lithics: denticulates and scrapes; fauna: bison, horse and reindeer (ibid)). Direct dating of the femur itself however showed it to be ~45,000RCY (Beauval et al. 2006). Like the Mousterian level at Les Cottés, level J contains carnivore remains and carnivore modified faunal remains, which has been taken as evidence that bioturbation particularly in the form of hyena denning accounts for the inclusion of more recent organic materials in level J (ibid). Such a scenario may be likely for the Mousterian level at Les Cottés.

The absence of carnivore modified faunal remains and the fresh nature of the lithic assemblages means that bioturbation is not a likely explanation for the overlap in the dating of the Protoaurignacian and first Early Aurignacian levels. It is tempting to suggest that this pattern was the result of a rapid depositional process —perhaps anthropic in nature such as burying of faunal waste. This may explain in part the inability to distinguish chronometrically the Protoaurignacian and first early Aurignacian horizons. Recently, the dating of the Protoaurignacian at Les Cottés has garnered some attention (Banks et al. 2013a, Higham et al. 2013). Assessing the provenience of the dated samples, Banks et al. (ibid) argue that the stratigraphic context of several samples cannot be confidently assigned. They only accept the results for two samples from the Protoaurignacian level. Their method of selection produces an average weighted mean for the *Protoaurignacian* of 34,790RCY and 33,976RCY for the first Early Aurignacian. These dates are in agreement with those proposed in Table **28**. The following provides a summary of chronostratigraphic analysis.

Level D (early Aurignacian):

This level yielded three radiocarbon dates that range from 32,590-31,640RCY. Two of the samples showed no signs of modification and one presented cut marks. The average age of the dating results is 32,078RCY (Talamo et al. 2012, 273). The averaged results for this level were the closest in age, about a thousand-year difference, when compared to the traditional radiocarbon results from materials excavated by Pradel. The only sample tested that demonstrated human modification yielded results around ~32,500RCY. The average age of the level results in a calibrated age of 35,975BP (SD = 301). This fits fairly well with the OSL results that indicate an age for this level of 37,200BP (SD = 1,500).

Level E (Protoaurignacian and early Aurignacian):

This level yielded nine radiocarbon dates. Six of the bone samples showed cut marks and the remaining samples showed no signs of animal and human modification. Individual dates for the Protoaurignacian and early Aurignacian could not be determined. This was due to the large overlap of the dates derived from the specimen samples from the lower and upper portions of Unit 4. The average age for Level E comes out to 34,060RYC while the total range spans 35,160-33,080RCY. The reassessment outlined in this chapter of the dating results of this level does not alter the age of the level to any significant degree, **34,100RCY** (SD = 293). This results in a calibrated age of 38,614BP (SD 353). This fits within the chronological range suggested by the OSL results, 41,000BP (SD 2,000).

Level G (Chatelperronian):

There were six samples from this level that yielded radiocarbon dates. Three of the samples showed signs of human modification, cut marks, and two of the samples showed no signs of modification. This horizon was the first to include a carnivore modified sample (n = 1). The average age of the samples is ~39,000RCY, however, Talamo et al. (2012, 179) dismiss the two oldest dates derived for this horizon as "outliers". The removal of these samples brings the average age forward to 37,500RYC. The reanalysis outlined in this chapter suggests that the former averaged age is more accurate. According to my analysis, the average age of the level is **39,593RCY** (SD = 667) with a range spanning 42,090-36,640RCY. The calibrated age is 43,397BP (SD = 562), fitting very well with the OSL results, 43,100BP (Jacobs et al. 2015, 118).

Level I (late Mousterian):

This level produced eight samples that yielded radiocarbon results. Half of the samples present human modification in the form of cut marks and use as bone retouchers. Three of the samples showed signs of having been digested. Talamo et al. (2012) removed the youngest sample date, as it extended into the age range documented for the first Aurignacian horizon. None of the samples were carnivore gnawed. The average age of the samples is ~39,200RCY. My reassessment of the radiocarbon dates results in an older average age for the level, **41,388RCY** (SD = 680) with a range spanning 42,690-38,970RCY. Calibration results in an age of 44,872BP (SD = 622) for this level. This date does not fit very well with the OSL results, 51,000BP (SD 3,000). The radiocarbon results are closer in age to the OSL results for US07, the sterile level that separates levels G and I, 47,000 (SD 2,000). The discrepancy between the radiocarbon and OSL results may be indicative of ancient contamination perhaps from bioturbation or a process of erosion during the Les Cottés interstadial.

Synthesis

1. No matter the method used to correct the chronometric information with the site stratigraphy, the age of each archaeological horizon under the new dating program is significantly older than previously assumed.

2. The reanalysis of the chronostratigraphy herein does not contradict the conclusion by Talamo et al. (2012, 182) that the Aurignacian commences at Les Cottés ~39,000 calibrated BP.

3. However, this analysis does not support the assumed rapid 1,000 years or less transition from the Chatelperronian to the Protoaurignacian argued by Talamo et al. (ibid).

Environmental Context

According to the sedimentological analysis by Frouin et al. (2013, 193), the archaeological levels at Les Cottés were formed during relatively stable and cold periods. Changes in the faunal spectrum indicate a gradual change from a steppic to an arctic environment (ibid). However, the chronology, spanning ~42,000-32,000RCY, suggests that the environmental backdrop during the formation of the site must have been more complex. Roughly speaking, archaeological deposition began just following the Heinrich 5 event while the final Aurignacian level formed during the Heinrich 4 event. Of course, the site is the namesake for the Les Cottés interstadial, a warm and wet period, recorded in the pollen spectrum of level H.

Level C:

As published analyses of this level are limited, in part due to its debated archaeological significance, reconstructing the level’s palaeoclimatic context is difficult. The dating results, which have not been re-examined unlike the underlying levels, indicate a significant unconformity in sediment formation between this level and level D. As such, at 23,420RCY combined with the pedological analysis suggesting formation during a relatively cold period, places the formation of level D just prior to the last glacial maximum.

Level D:

The decrease in pollen at the site level (Bastin et al. 1976) and at the regional level (Sánchez Goñi et al. 2008) indicates a very cold and arid environment. This is in agreement with the pattern of fauna from this level, which indicate an arctic, tundra-like ecological context. The dating of the site, at 32,078RCY (Talamo et al. 2012, 273), combined with the palynological and faunal evidence, suggests that level D formed during the Heinrich 4 event (H4). Sedimentological analysis, however, does not necessarily indicate the cold conditions expected from H4. However, the dating of level overlaps with the end of H4 just after the event, 38,000BP (Hemming 2004, 28 fig. 24), which may explain this small discrepancy.

Unit 03:

Palynological evidence at the site (Bastin et al. 1976) and regional (Sánchez-Goñi et al. 2008) level, indicates a comparatively warmer and perhaps less arid environment. Capped between level D, dated to ~32,000RCY, and level E, dated to ~34,000RCY, unit 03 most likely corresponds to Greenland interstadial 9 and D/O 10.

Level E:

The site level pollen spectrum indicates a cool open environment (Bastin et al. 1976). Regional palynological analysis indicates a similar spectrum (Sánchez-Goñi et al. 2008). This is indicative of a more steppe like environment compared to the arctic context of level D. The faunal pattern and sedimentological analysis support this interpretation (Frouin et al. 2013). Given dating of the level to ~34,000RCY, biological and sedimentary markers most likely indicate a correspondence with the Greenland stadial 10.

Level F:

The site level pollen spectrum (Bastin et al. 1976) indicates a growth in grass species. The regional palynological analysis indicates that this event was longer lasting but not as pronounced as Greenland interstadial 9, recorded in unit 03. There is a significant chronological gap between level E, dating to ~34,000, and level G, dating to

~40,000RCY. This makes it difficult to be certain about the precise date of level F, but it most likely formed during Greenland interstadial 10 and D/O 11.

Level G:

The pollen spectrum from the level shows a significant, prolonged reduction in the abundance of floral species (Bastin et al. 1976). This trend is mirrored in the regional palynological analysis (Sánchez-Goñi et al. 2008), but appears less pronounced. The sedimentological analysis (Frouin et al. 2013) indicates that this drop in floral abundance was coupled with an equally long and pronounced drop in temperature. The faunal pattern matches such a scenario with the increase in reindeer and near absence of horse suggesting a very cold and arid steppic environment. With a date around 40,000RCY, level G most likely corresponds to Greenland stadial 11.

Level H:

The pollen spectrum from this level was used by Bastin et al. (1976) to define the Les Cottés interstadial. During this event, the surrounding landscape would have been partially forested or clustered with patches of tree stands. This is indicated by the dominance of tree pollen with pine and oak accounting for nearly 70% of the floral species (ibid, 1263). The overall climate must have been relatively mild for MIS3, as ivy and chestnut pollen are also present at 1.5% and 0.5% respectively (ibid). Therefore, level H formed during an environmentally and ecologically distinct period compared to the rest of the site sequence.

Prior to the redating of the site by Talamo et al. (2012), the Les Cottés interstadial was thought to correspond with Greenland interstadial 8 (Baales 2012, 135). Now that the superimposed level G has been pushed back in age some six thousand years, the Les Cottés interstadial cannot be the same event as the Greenland interstadial. Rather, the event is probably the same as the older Hengelo interstadial as has been suggested for some time now (Harrold 1981, 7). Therefore, level H probably relates to D/O 12, which is often associated with the Hengelo interstadial (Bosselin 2003, 125 table 1), and on chronological grounds, must relate to Greenland interstadial 11 (Svensson et al. 2006, 3260 fig. 1).

Level I:

The site level palynological analysis (Bastin et al. 1976) and sedimentological study (Frouin et al. 2013) indicate a cold environment. This fits well with the pattern of faunal species recovered from this level, which suggest a steppic environment (Frouin et al. 2013, 193). Dating to 42,000RCY or older, the level most likely formed toward the end of the Heinrich 5 event.

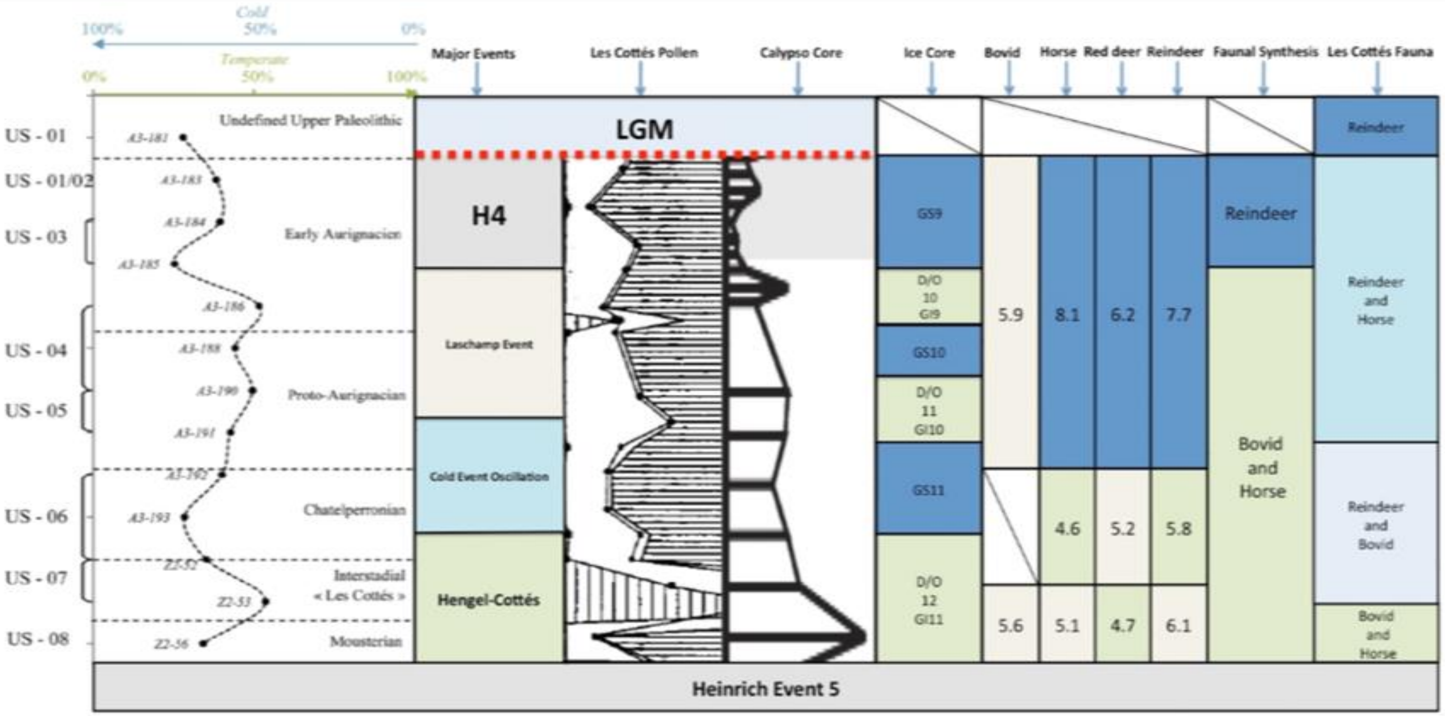


Figure 65. Les Cottés environmental synthesis. From Left to right: temperature estimates from Frouin et al. 2013, 196, fig. 13, Laschamp Event date from Nowaczyk et al. 2012, tree pollen: left from Bastin et al. 1976, 1262—Les Cottés sequence, right from Sánchez Goñi et al. 2008, 1144 fig. 5 Bay of Biscay Calypso core, Greenland ice core from Blockley et al. 2012, 4 table 1, D/O from Sánchez-Goñi et al. ibid, Isotopic data (δ^{15}N-av) from Bocherens et al. 2014, 36 table 3, faunal synthesis from Discamps 2014, 3 fig. 1.

Synthesis:

1. The environmental backdrop to the formation of the Les Cottés sequence (Figure **65**) was far more complex than environmental indicators from the anthropic horizons suggest.

2. The site chronology itself indicates that the Middle to Upper Palaeolithic transition at Les Cottés spanned D/O 11, 10, 9, and 8 (Bosselin and Djindjian 2002, 277 fig. 2).

3. Nevertheless, human occupations of the site coincide with stadial events.

4. As such, both the Neanderthal and AMH occupations occurred during cold periods within a largely open landscape.

5. These occupations begin when surrounding landscape was steppic like.

6. Occupations of the site continued as the environment became more arctic, becoming tundra like during the formation of level D, the last Aurignacian occupation of the site.

Discussion

Les Cottés is an important site for many reasons. The site's archaeological sequence records a full Middle to Upper Palaeolithic transition (late Mousterian > Chatelperronian > Protoaurignacian > Early Aurignacian). The Chatelperronian assemblage is relatively large for this industry (Harrold 1981). While the *pointes des Cottés* (Pradel 1952) suggest a greater complexity and diversity within the Chatelperronian. The occurrence of the Protoaurignacian within the site sequence affirms the existence of this industry in the Paris Basin, which is far outside its assumed Mediterranean confines. Beyond all this, Les Cottés is the type-site for the interstadial event of the same name that marks a pronounced geological boundary between Middle Palaeolithic and Upper Palaeolithic deposits across Western Europe (Lévêque 1997, Mellars 2002, d'Errico and Sánchez Goñi 2003).

Consequently, the redating of the site (Talamo et al. 2012) has the potential to rewrite the timing of the Middle Upper Palaeolithic transition and, with it, the replacement of Neanderthals by AMHs. Further, the latest radiocarbon and OSL testing of the site have been vital aids in better defining the relationship of Les Cottés singular site level environmental information with regional and global palaeoclimatic data. In turn, a fuller picture of associated climatic, ecological, and archaeological patterns can emerge.

While the environmental backdrop during the formation of the stratigraphy of the site was complex, human occupations occurred during cold, stadial periods. The established trend in the archaeological levels demonstrates a progression of a cold steppe to an arctic and tundra like environment. As such, the percentage of reindeer steadily increases in the faunal assemblages until the final Aurignacian level where reindeer account for 97% of the assemblage. Isotopic analysis carried out by Bocherens et al. (2014) on a large sample of south-western French faunal remains recovered from transitional sequences indicates that severe ecological deterioration following the Les Cottés interstadial, culminating in the extreme conditions of the Heinrich 4 event. This fits well with the palaeoclimatic evidence and faunal pattern recorded in the Les Cottés sequence.

The faunal pattern is associated with a similar progression in the percentage of non-local material sources in the lithic assemblages. This pattern may suggest that the Palaeolithic occupants of Les Cottés were subject to the same environmental pressures that affect modern hunter-gather territoriality and demography as described by the Band Model.

Conclusion

This chapter provided a detailed description of the transitional sequence at Les Cottés. As such, excavation results from the work carried out by Louis Pradel in the latter half of the 20th century and the recent testing under the direction of Marie Soressi were synthesized. This allowed a full discussion of the site stratigraphy, archaeological and faunal patterns, chronology, and palaeoenvironmental context.

Out of this discussion, an association between the changes in the faunal assemblage and raw material sourcing patterns emerged. The relationship is examined more fully using the heuristic and statistical models outlined in chapter 7. Prior to this, however, Geissenklösterle and Hohle Fels are discussed in order to provide a comparative basis in the analysis of fission-fusion behaviours during the Middle and Upper Palaeolithic. The following chapter therefore includes an examination of published materials on these Swabian sites similar in format to the one provided here for Les Cottés.

CHAPTER 10

Case study part II: Geissenklösterle and Hohle Fels

Introduction

The Swabian transitional sequences at Geissenklösterle and Hohle Fels provide a good juxtaposition to the patterns observed within the Les Cottés case study for several reasons: the earliest Aurignacian horizons in the Jura are argued to be as old if not older than the classic Early Aurignacian sites of southwestern France (Higham et al. 2012), the cultural sequence is unique and importantly different from that of Les Cottés, and it provides a different geographical and palaeoenvironmental setting. These all add to the ultimate assessment of the fission-fusion behaviours of late Neanderthal and early AMH populations. There are several sites within the Ach and Lone valleys, but Geissenklösterle and Hohle Fels have been subject to the most extensive and modern excavation methods (Conard and Bolus 2003, 211; Conard 2011, 231). Excavations are in fact ongoing at Hohle Fels. I was fortunate enough to have spent a limited amount of time excavating at this site, and to a small extent, this experience has shaped the following analysis of Jura transitional sequences. However, due to the ongoing nature of research at Hohle Fels, published data on this site is generally more limited than information pertaining to Geissenklösterle.

The examination of Geissenklösterle and Hohle Fels follows a similar format to that of Les Cottés in the previous chapter. The chronostratigraphic contexts of the sites are, however, presented earlier in this chapter because they play a greater role in the subsequent examination of other aspects the Geissenklösterle and Hohle Fels sequences. Archaeological and environmental data from both sites generally mirror one other. For this reason, the discussion of the sequences that form Geissenklösterle and Hohle Fels are presented in a synthesized outline. The one exception to this is the discussion of site stratigraphy where the two sites differ in the formulation of their archaeological levels and geological layers.

Comparative study area

The sites of Geissenklösterle and Hohle Fels, located in the Ach Valley of the Swabian Jura, Germany (Figure 66) are famous for their archaeological finds, particularly the Aurignacian levels, which contain a record of extraordinary artistic and musical artefacts (Hahn 1972; Münzel et al. 2002; Conard 2003; Conard and Malina 2008; Conard et al. 2009; Conard 2009; Higham et al. 2012). In fact, Ucko and Rosenfeld

(1967) consider the tradition of symbolic material cultural found within the Aurignacian record of Swabia to be one of the earliest examples of artistic expression in the world. Further, the Aurignacian deposits from Geissenklösterle have been argued to be the earliest evidence of AMHs in Europe (Higham et al. 2012).

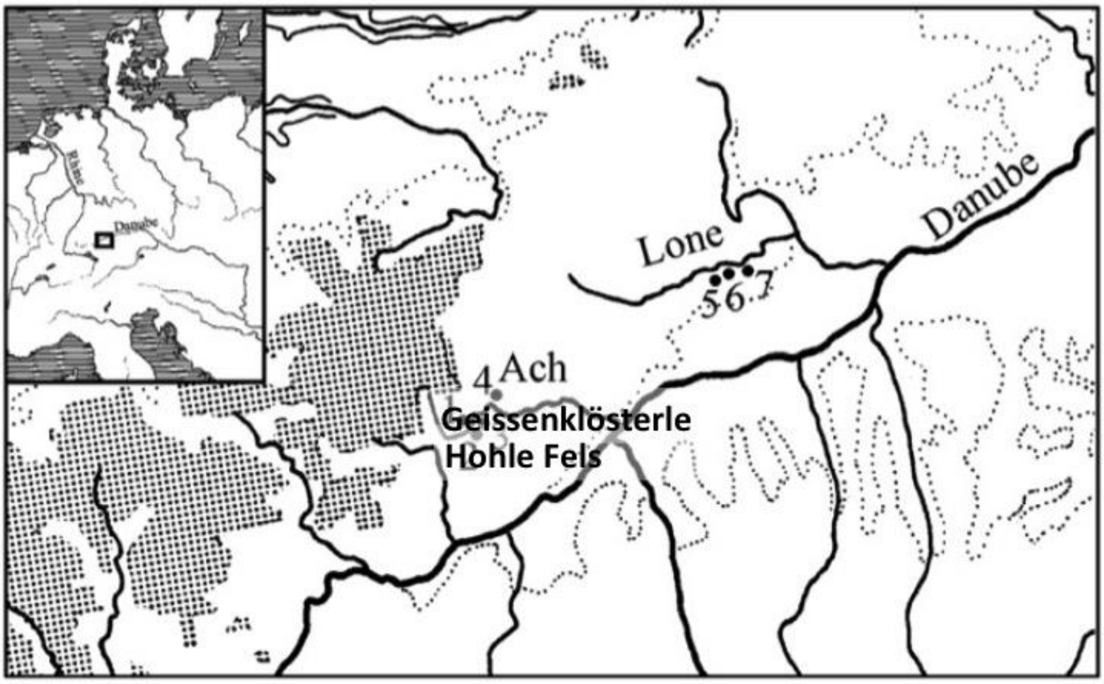


Figure 66. Geographical location of Geissenklösterle and Hohle Fels. Modified from Hardy et al. 2008, 650 fig. 1.

The exceptional artistic and musical artefacts coupled with the early dating results from the Swabian Aurignacian form the basis of the *Kulturpumpe* model (Conard and Bolus 2003). This model argues that early modern humans migrated into Europe along the Danube corridor where, through interspecies competition with native Neanderthal populations and further demographic pressure, the full Aurignacian repertoire emerged before spreading throughout Western Europe. This model has sparked interests as well as intense debate (Zilhão and d'Errico 2003a; Verpoorte 2005; Conard et al. 2003; Conard and Bolus 2006; Higham et al. 2012).

Research History:

Hohle Fels has a longer research history; in fact, one that is ongoing. Oscar Fraas first began excavations within Hohle Fels in the 1870s (Bolus and Conard 2012, 67). Robert Schmidt began a small but systematic study of the cave's cultural levels and sediment formation in 1906 (Bolus and Conard 2012, 71). Gustav Riek began work in the cave in the first half of the 20th century. Following a long hiatus, Hahn began work on stratigraphic sections left behind from the excavations by Fraas and Riek in Hohle Fels. Following Hahn's death, excavation in Hohle Fels recommenced in 2001 under the direction of Nicholas Conard (Bolus 2003, 154).

Despite the long history of excavations at Hohle Fels, research has been more systematic and thorough at Geissenklösterle. This case may change in the future, but until the completion of ongoing work in Hohle Fels, the excavations at Geissenklösterle will remain the most formative concerning the Palaeolithic occupation of the Swabian Jura. In the early 1970s, Eberhard Wagner was the first to excavate the cave (Conard and Bolus 2006, 216). Joachim Hahn followed shortly after with a systematic excavation of the cave, which set the standard for future research on the Swabian Aurignacian (ibid). After Hahn's death in 1997, Conard continued excavations, which are ongoing, in Geissenklösterle starting in 2000 (Bolus 2003, 154).

Stratigraphy of Geissenklösterle and Hohle Fels

Excavation of Geissenklösterle and Hohle Fels has been done according to geological or context horizon and archaeological level. Starting with Hahn's study of Geissenklösterle and publication of the cave's Aurignacian finds (1988), archaeological deposits have been synthesized into cultural horizons for purposes of artefactual, faunal, and chronometric analyses. As such, Geissenklösterle's Aurignacian horizon was excavated according to 8 separate levels and then synthesized into 2 cultural horizons (Bolus 2003), which are sometimes subdivided into upper and lower horizons themselves. Hohle Fels has been treated in the same manner (Figure 67).

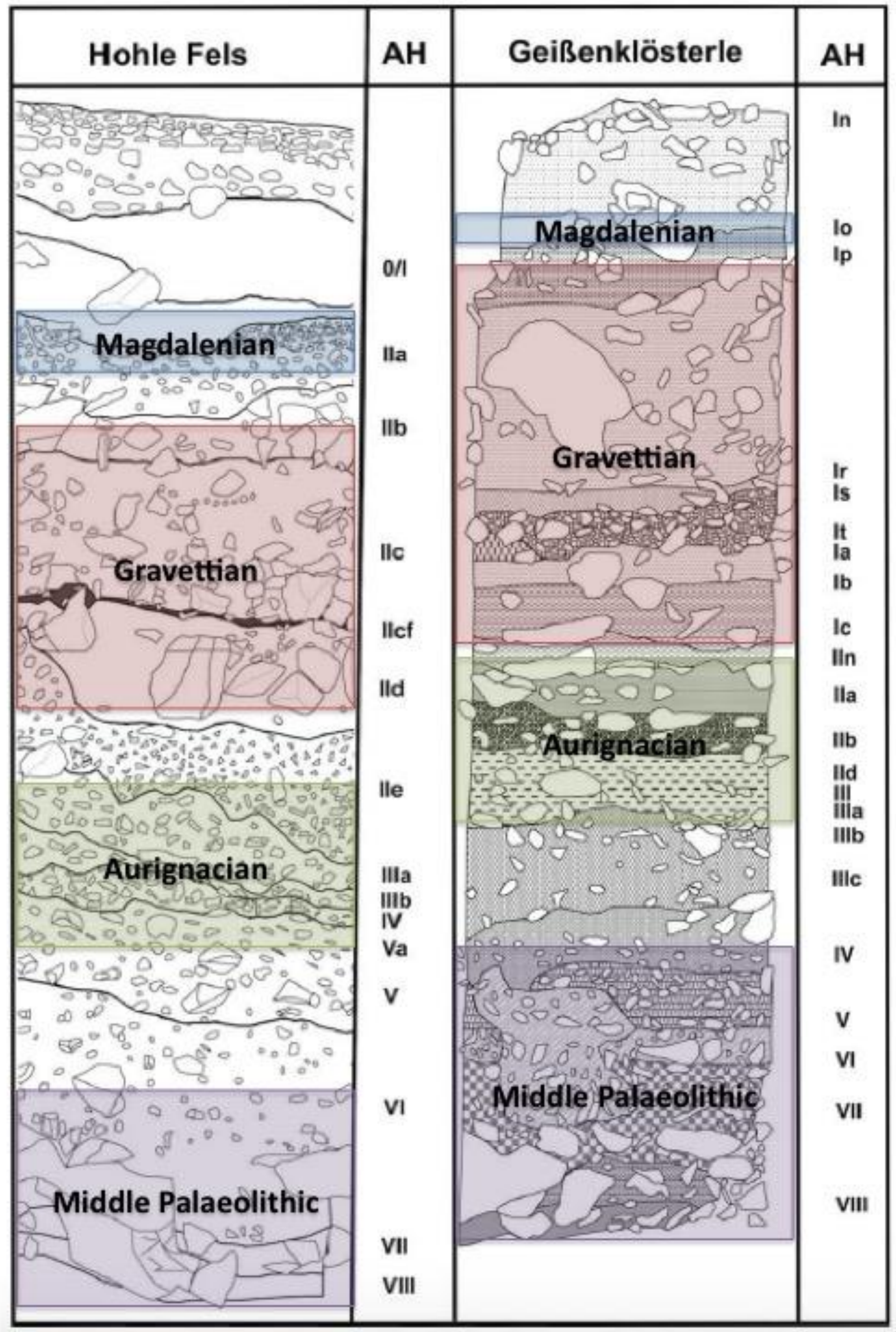


Figure 67. Stratigraphic profiles from Hohle Fels and Geissenklösterle. Modified from Conard and Bolus 2008, 888 figure 2.

Geissenklösterle:

The Palaeolithic sequence at Geissenklösterle contains deposits from the Middle Palaeolithic to the Magdalenian. There is a substantial occupational hiatus between the Middle Palaeolithic and Aurignacian horizons as indicated by a 20cm thick sterile sediment layer (Richter et al. 2000, 72).

-Magdalenian

The Magdalenian horizon only composes one archaeological level, AH IO. This level is found within the geological layer GH. (Hahn and Owen 1985, 62 fig. 1)

The geological matrix is composed of fine eboulis cave fall, sand, and other rubble (Richter et al. 2000, 72).

-Gravettian

The Gravettian horizon is more extensive than the superimposed Magdalenian. According to Hahn's cultural division, archaeological levels AH Is, It, Ia, and Ib compose the Gravettian horizon (Hahn and Owen 1985, 62 fig. 1; Hahn 1988). The underlying archaeological level, AH Ic is now considered to belong to the Gravettian as well (Conard and Bolus 2003; Conard and Bolus 2008; Higham et al. 2012). The archaeological levels belong to the geological layers GH 6, 7, 8, 9, 10 (Hahn and Owen 1985, 62 fig. 1). These geological levels are composed mostly of eboulis cave fall in a silty clay matrix (Richter et al. 2000, 72).

-Aurignacian

The Aurignacian deposits were excavated according to several archaeological levels, AH Ic, IIn, IIa, IIb, IId, III, IIIa (Hahn and Owen 1985, 62 fig. 1). The underlying levels AH IIIb and IIIc are sometimes also counted as archaeological levels belonging to the Aurignacian (Conard 2006; Conard and Bolus 2008; Conard 2011). The archaeological levels belong to the geological layers GH 11, 12, 13, 14, 14, and 16 that are mostly composed of eboulis cave fall in a clay matrix (Richter et al. 2000, 72).

-Middle Palaeolithic

The Middle Palaeolithic deposits are mostly confined to archaeological level AH IV but do extend down to levels AH V, VI, VII, and VIII (Conard 2011). The upper portions of archaeological levels belong to geological layers GH 19 and 20, which are composed of eboulis in a sandy, clay rich matrix (Richter et al. 2000, 72).

Hohle Fels:

The archaeological sequence at Hohle Fels mirrors that of Geissenklösterle. Four archaeological periods are recorded at the site, Magdalenian, Gravettian, Aurignacian, and Middle Palaeolithic. Like Geissenklösterle, a sterile level 50cm in thickness separates the Middle Palaeolithic and Aurignacian (Conard and Bolus 2008).

-Magdalenian

The Magdalenian belongs to archaeological levels AH I to I/IIb (Goldberg et al. 2003, 6-7 table 1), but with highest concentration of finds coming from AH I and IIa (Münzel and Conard 2004b). The levels correspond to geological layers GH 1k, 1gb, 1s, 3as, 3ad, which is mostly composed of a silty clay with limestone gravel (Goldberg et al. 2003, 5-6 table 1).

-Gravettian

The archaeological levels containing Gravettian deposits are AH IIb, IIbf, IIc and IIcf with IIbf and IIcf being associated with ash and burnt bone lenses (Goldberg et al. 2003, 6 table 1; Münzel and Conard 2004a). The archaeological levels are found with geological layers GH 3b, 3bt, 3c, and 3cf, which are primarily composed of silts, clay and limestone gravel (Goldberg et al. 2003, 6 table 1).

-Aurignacian

The Aurignacian horizon is found in archaeological levels AH IId, IIe, IIIa, IIIb, IV, Va, and Vb (Goldberg et al. 2003, 6 table 1, Conard 2011). However, the archaeological affinity of AH IId and IIe is uncertain as to whether they are Gravettian or Aurignacian (Conard and Bolus 2008, Conard 2011). The upper archaeological levels are found in geological layers GH 3d, 5, and 6, which are largely composed of clayey silts with limestone gravels (Goldberg et al. 2003, 6 table 1).

-***Middle Palaeolithic***

Archaeological levels AH VI, VII, VIII, and IX comprise the Middle Palaeolithic horizon (Conard and Bolus 2008). Work on the Middle Palaeolithic levels is on-going, so sedimentation processes are not well defined at this point (Conard et al. 2012). The archaeological levels belong to geological layers GH 9, 10, 11, 12 (Conard and Bolus

2008, 895 fig. 6). The Middle Palaeolithic geological layers are on average thicker than the superimposed Aurignacian levels (Conard 2011, 232 table 19.1).

Synthesis:

1. Geissenklösterle and Hohle Fels present similar archaeological sequences, Middle Palaeolithic => Aurignacian => Gravettian => Magdalenian.

2. At both sites, there is sterility between the final Middle Palaeolithic and Aurignacian.

3. Despite these very significant similarities, there are some general differences in the sediment and thus site formation process between the two caves.

4. Eboulis is much more common at Geissenklösterle, and some geological layers are composed mostly of eboulis, gravel, and sands.

5. Clay and silts, on the other hand, seem to compose a greater portion of the sediment in Hohle Fels.

Chronology of Geissenklösterle and Hohle Fels

The Swabian Aurignacian, particularly the earliest Aurignacian deposits from Geissenklösterle, is considered to be the oldest evidence of this industry and thus AMHs in Europe (Richter et al. 2000; Bolus and Conard 2001; Conard and Bolus 2003; Conard et al. 2003; Conard and Bolus 2006; Conard and Bolus 2008; Higham et al. 2012; Higham et al. 2013). Concerns have been raised over the reliability of the oldest dates from the lower most Aurignacian level, AH III, that suggest an age greater than 41kya (Zilhão and d'Errico 1999; Zilhão and d'Errico 2003a; Zilhão and d'Errico 2003b; Verpoorte 2005; Banks et al. 2013). Such controversies have not been raised by the dating results from Hohle Fels, which suggest a dating range for the lower most Aurignacian levels at that site from ~32,000RCY to ~34,000RCY (Conard and Bolus 2008, 890 table 2). The following examination looks more closely at the chronology of Geissenklösterle.

Geissenklösterle:

Contention over the Jura Aurignacian stems from the claim that this complex is older than similar archaeological contexts in France and northern Iberia as argued in the *Kulturpumpe* model (Conard and Bolus 2003). Issues have been raised over the cultural affinity of the lowermost Aurignacian level, AH III, the stratigraphic integrity of the lowermost level, and the anthropogenic origin of the samples that have been chosen for dating.

-Cultural affinity

Hahn, in his seminal monograph on the Aurignacian levels from Geissenklösterle (1988), classified the lowermost Upper Palaeolithic level in the sequence, AH III, as belonging to the Protoaurignacian industry. Bolus (2003, 155) points out that this typological designation was due to the absence of split based bone points, a low rate of Aurignacian retouch on blades, and a high percentage of carinated end scrapers. This raised doubts as to the Aurignacian nature of the archaeological assemblage (Zilhão and d'Errico 1999). Subsequent to this critique, the AH III assemblage has been reappraised and is now considered to be more typologically similar to the Early Aurignacian (Bolus 2003; Teyssandier and Liolios 2003).

-Integrity of archaeological levels

The lowermost Aurignacian level, AH III, is subdivided into AH IIIa, IIIb, and IIIc. For purposes of post excavation analysis, finds from levels IId to IIIb are often treated as one cultural horizon (Conard 2006; 2011). As these levels by and large belong to geological layers GH 14 and 15, synthesizing the Aurignacian into one horizon makes sense. However, this also casts doubt on the legitimacy of singling out very early dates from any one of these levels. Further, AH IIIc is "largely a sterile layer" (Conard and Bolus 2008, 888). There are other important reasons to questions whether the lowermost Aurignacian levels represents stratigraphically secure living surface or single events (Zilhão and d'Errico 1999; 2003a).

Zilhão and d'Errico (1999, 2003a, b) as well as Hahn himself (1988), note that post-depositional disturbances are cause for concern at Geissenklösterle. Hahn estimated that at least 7% of the recovered artefacts were subject to vertical movement between archaeological levels and that another 30% were subject to horizontal movement (Zilhão and d'Errico 2003b, 328).

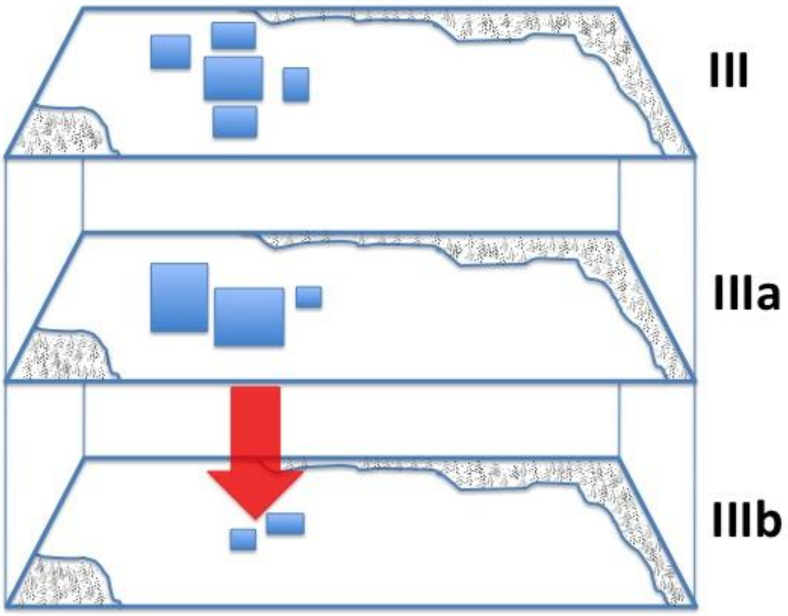


Figure 68. Hypothesized downward sorting of materials within the lowermost Aurignacian horizon at Geissenklösterle (after Hahn 1988, 93 fig. 310).

To this end, dating results from level AH III, and throughout the Aurignacian horizon, are actually quite noisy when placed in stratigraphic order with results ranging from 29,000KYA to 40,000KYA (Conard and Bolus 2008, 887). However, there does seem to be a clear early event, a processing of reindeer around a hearth feature within the relatively small but perhaps semi-intact archaeological level AH IIIa (Hahn 1988; Zilhão and d'Errico 2003a). On consideration, this level may be indicative of the first actual Upper Palaeolithic occupation of the site. Therefore, vertical movement (Figure **68**) as shown by lithic refitting is a problem at Geissenklösterle (Hahn and Owen 1985; Hahn 1988).

-Anthropogenic origin of the dated samples

Humans were not the only accumulators of organic materials in the cave (Münzel 1997; Münzel 2001; Münzel and Conard 2004a). Added to this, there is major unconformity both archaeologically and geologically in the part of the sequence that directly underlies the earliest Aurignacian deposits, GH 16 and 17. According to Hahn (1988, 46), stratigraphic level GH16 formed during the Les Cottés interstadial.

The analysis of the type-site for this interstadial, Les Cottés, presented in the last chapter, indicates that GH 16 should date to ≥40,000RCY. Results off the temperate species, *C. elaphus*, from sterile level IIIc, located within the summit of GH16, produced a date of 39,400RCY (Oxa21657 Higham et al. 2012, 669 table 2), conforming to dating range of the interstadial event. Further, the presence of red deer continues from GH 16 into the base of GH14/15, suggesting perhaps that these layers formed within deflated sediments from the Les Cottés/Hengelo interstadial[1].

The earliest Aurignacian levels, AH IIIa and IIIb are located within these geological layers, giving the Swabian Aurignacian the appearance of greater antiquity. However, complex taphonomic processes should not be overlooked as a possible explanation for the very early dating results of the lower most Aurignacian levels at Geissenklösterle.

To this end, the very earliest dates for the Aurignacian come from remains of roe deer (Zilhão and d'Errico 2003a), which like red deer, are at odds with the otherwise cold, boreal environmental signal of the Aurignacian horizon (Conard et al. 2006 table 1). For these reasons, the assessment of the chronology of human activities at Geissenklösterle laid out below (Table 29) follows the suggestion made by Banks et al. (2013a) that only dates derived from samples of butchered or otherwise processed game species such as "ibex, reindeer, and horse" should be utilized. Hahn also believed the presence of these species in the cave to have been of anthropic origin (Conard and Bolus 2003, 355).

Level	**Culture**	**Mammoth**	**Lab #**	**Date**	**Notes**
Ir	G		OxA 4867	27500	
It	G		OxA 5226	26540	
It	G	**X**	OxA 5229	27950	
Ic	G		OxA 21661	32900	from Higham et al 2012
Ic	G		OxA 5160	30300	remove
Ic	G		OxA 18718	33380	remove from same sample
IIa	UA		OxA 18713	33000	
IIa	UA		OxA 5707	33200	

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[1] Though this critique is not an intentional rehashing of previous arguments, Zilhão and d'Errico (1999; 2003a; b) and Banks et al. (2013a) have previously noted these concerns.

Table continued

IIa	UA	X	OxA 21724	33950	Same as below. New date from Higham et al. 2012
IIb	UA	X	KIA 8960	29800	Remove
IIb	UA		OxA 21726	34200	from Higham et al 2012
IIb	UA		KIA 8958	31870	
III	LA		OxA 6256	30100	remove
III	LA		KIA 8963	31180	
III	LA		KIA 16031	35060	
III	LA		OxA 21659	35050	same sample as below from Higham et al. 2012
III	LA		OxA 18716	35700	remove same sample as OxA 6256
IIIa	LA		KIA 19555	32910	
IIIa	LA		OxA 21746	36850	same sample as below from Higham et al. 2012
IIIa	LA		KIA 13075	34330	remove
IIIa	LA		KIA 16030	34770	
IIIa	LA		OxA 21745	36650	same sample as below from Higham et al. 2012
IIIa	LA		KIA 13074	34800	remove
IIIa		X	OxA 21721	37300	same sample as below from Higham et al. 2012 and cultural level changed
IIIa	LA	X	KIA 8962	28640	removed too young
IIIb	LA		KIA 16033	32670	
IIIb	LA		KIA 17302	33900	
IIIb	LA		OxA 21743	36100	same sample as below from Higham et al. 2012
IIIb	LA		KIA 13076	34080	remove
IIIb	LA		KIA 16032	36560	(Roe deer) Zilhao and d'Errico (2003) argue that this material actually belongs to the underlying sterile horizon
IIIc	Les Cottés/Hengelo				
IIIc	S		OxA 21657	39400	(Red deer) from Higham et al. 2012
IIIc	S		OxA 21658	38300	(Ibex) from Higham et al. 2012

Table 29. Dating results for Geissenklösterle (Conard and Bolus 2008; Higham et al. 2012). Red highlights dates that have been removed.

Mammoth has also been another suggested prey species (Münzel 2001; Münzel and Conard 2004). However, the dating of mammoth samples is often out of synch with the samples derived from other suggested prey species (Table 30). This suggests that mammoths were probably not hunted by humans and that mammoth skeletal elements in Geissenklösterle are not food waste. More likely, mammoth bone and ivory would have been collected from bone beds as a source of raw material as suggested by the manufacturing debris (Münzel 2001; Niven 2003, 201). Therefore, the occupants of Geissenklösterle, like other Palaeolithic peoples (Baryshnikov and Hoffecker 1994), exploited mammoth bone beds, bringing materials within them back to their camps.

Level	Culture	Date	Level	Culture	Date sans Mammoth	Delta
Ir	G	27500	Ir	G	27500	0
It	G	27245	It	G	26540	705
Ic	G	32900	Ic	G	32900	0
IIa	UA	33383	IIa	UA	33100	283
IIb	UA	33035	IIb	UA	33035	0
III	LA	33763	III	LA	33763	0
IIIa	LA	35295	IIIa	LA	35295	0
IIIb	LA	35306	IIIb	LA	34223	1083

Table 30. Average ages of the archaeological levels at Geissenklösterle with mammoth specimens and without mammoth species included.

Removing the mammoth samples as well as ones that produced multiple incongruent results leaves a dataset that is more reflective of the true age of the archaeological levels at Geissenklösterle. It has been noted that the Geissenklösterle sequence presents a "noisier" signal compared the linear chronology of the Hohle Fels sequence (Conard and Bolus 2008, 894). With the sampling criteria above, the discrepancies between the dating of Geissenklösterle and Hohle Fels are significantly reduced.

-Magdalenian

The age of the Magdalenian horizon at Geissenklösterle is not in dispute. Dating results show that it has an average age of ~13,000RCY (Hahn and Owen 1985, 62 fig. 1; Hahn 1988). This fits exactly with the radiocarbon results from Hohle Fels, ~13,000RCY (Goldberg et al. 2003, 5 table 1).

-Gravettian

With the adjustments proposed in this chapter, the Gravettian horizon has an average age of ~27,000RCY with a range spanning 26,540-33,380RCY. This fits well with the age of the Gravettian horizon at Hohle Fels, which has produced dating results ranging from ~26,000RCY to ~28,000RCY (Conard and Bolus 2008, 890 table 2).

-Aurignacian

The dating of the results from the Aurignacian level has been the most hotly debated. Filtering the dating samples as done above results in an age of ~32,000RCY for the 2nd upper Aurignacian level, ~33,000RCY for the 1st upper Aurignacian level, ~33,700RCY for the 2nd lower Aurignacian level, and ~34,700RCY for the 1st lower Aurignacian level. This results in a range spanning 32,670-36,650RCY for the earliest Aurignacian horizon. These dates fit very well the chronological range of the Aurignacian horizon from Hohle Fels, which spans 29,000RCY to 35,000RCY (Conard and Bolus 2008, 890 table 2).

-Middle Palaeolithic

The sterile layer that separates the Aurignacian and Middle Palaeolithic horizons formed during the Les Cottés/Hengelo interstadial, having a date of ≥39,000RCY. To this end, the Middle Palaeolithic horizon at Geissenklösterle must be older than this date. The same must also be true for the Middle Palaeolithic horizon at Hohle Fels, as testified by the only 'probable' cutmarked sample, which produced an age of 39,580RCY (Conard and Bolus 2008, 890 table 2).

Synthesis:

1. The assumption that the earliest Aurignacian horizon at Geissenklösterle is older than 40,000KYA is little supported upon careful consideration.

2. The GH 16/17 is most likely a product of the Les Cottés/Hengelo interstadial around 40,000RCY as indicated by the dating results off materials from level IIIc.

3. The early dates in association with Aurignacian artefacts, especially in level IIIb, are most likely a result of mixing within older parent materials dating from the Les Cottés interstadial.

4. As Zilhão and d'Errico (1999; 2003a; b) have argued, presence of interstadial species such as red deer and roe deer within the level III faunal assemblage suggests mixing and further geological disturbance.

5. I have argued that the level IIIb is most likely highly disturbed and that some of the materials from this level are derived both from intrusive materials.

6. Hahn recognized this issue and thusly did not treat level IIIb as a true archaeological level in his monograph.

7. The lower Aurignacian at Geissenklösterle begins at ~36,500RCY (average of OxA21745, 21746, 21743 from Higham et al. 2012, 669 table 2) and has an average age of ~35,000RCY from anthropically modified samples, so 36,500RCY should be considered the absolute oldest age for the Swabian Aurignacian.

8. Therefore, the most probable early onset of the Swabian Aurignacian coincides with the Protoaurignacian at Les Cottés and not the Chatelperronian. Even if the earliest dates for archaeological level III are taken into account, as Higham et al. (2012) suggest, 37,800 (OxA21723) and 37,300 (Oxa21721), then the Lower Aurignacian is still some 2,000RCY younger than the Chatelperronian at Les Cottés and at least 3,000RCY younger than the majority of Chatelperronian levels, which are found in Les Cottés/Hengelo geological layers (Lévêque 1997).

9. However, the earliest dates are derived from archaeological horizon IIIb and were taken off of an unmodified horse femur and from mammoth, which, as noted earlier, can produce radiocarbon results thousands of years older than other stratigraphically associated samples.

10. Once the mammoth and the single roe deer sample are removed, averaged age of AH IIIb is 1000RCY younger than averaged age for IIIa, highlighting the chronostratigraphic issues of the earliest Aurignacian deposits from Geissenklösterle.

Archaeological Sequence

The archaeological sequences at Geissenklösterle and Hohle Fels show a similar cultural chronology. As previously noted, the Middle Palaeolithic levels start at the base of both sequences. These are superimposed by an Aurignacian horizon then a Gravettian horizon with the final Palaeolithic being represented by the Magdalenian at both sites.

Magdalenian:

The Magdalenian industry at Hohle Fels (Figure 69) is primarily represented by backed bladelets, which account for nearly 50% of the tools in the lithic assemblage (Taller et al. 2012, 40). Bone and antler projectiles typical of the Magdalenian as well as bone needles are also present (Goldberg et al. 2003, 7).

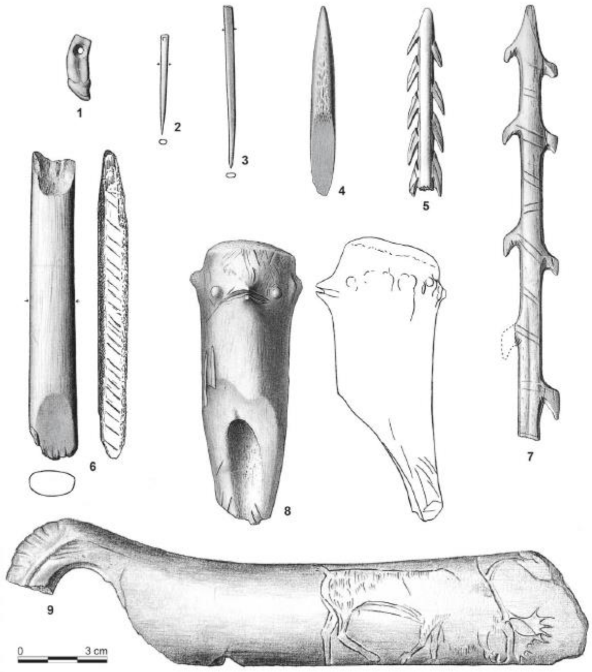

Figure 69. Osseous artefacts typical of the Magdalenian excavated and drawn by Schmidt during his early 20th century research at Hohle Fels. Copied from Bolus and Conard 2012, 83 fig. 10.

The Magdalenian from Geissenklösterle is poorly represented, but blade and bladelet blank production was the primary focus of reduction strategies within the assemblage as typical of the Swabian Magdalenian as a whole (Hahn and Owen 1985, 74).

Gravettian:

Reduction strategies during the Gravettian were primarily directed at the production of backed elements, mostly bladelets, which comprise ~30% of tools in the lithic assemblage (Moreau 2010, 82). Like the later Magdalenian, bladelets are predominant if only to a smaller degree. Münzel (2004) notes that the Gravettian compared to the underlying Aurignacian presents a greater degree of debitage and unretouched flakes/blades, whereas the Aurignacian brought and deposited more formal tools and left less evidence for primary reduction on site. Of course, both of the Gravettian assemblages from Hohle Fels (Figure 70) and Geissenklösterle are rich in both symbolic and functional, osseous materials (Conard and Bolus 2003).

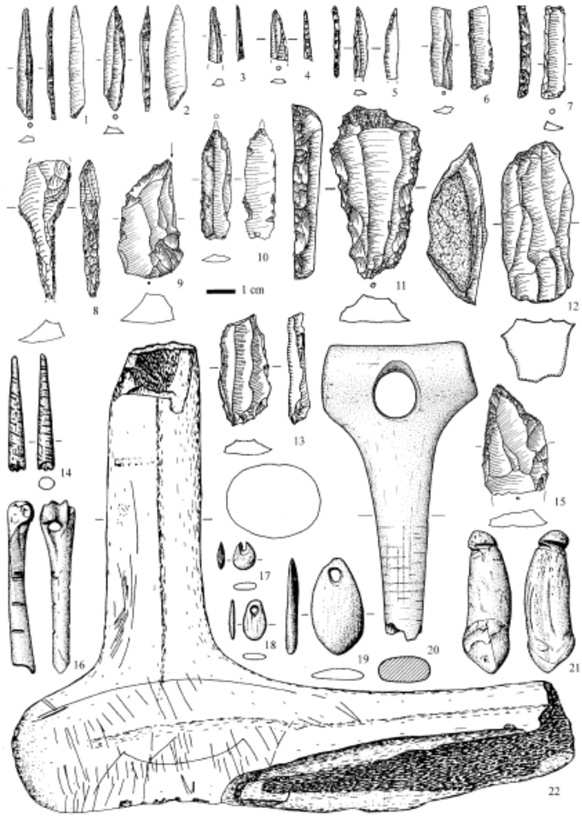

Figure 70. Representative artefacts of the Swabian Gravettian from Hohle Fels. Copied from Conard and Bolus 2003, 349 fig. 9.

Aurignacian:

The Aurignacian horizons at Geissenklösterle (Figure 71) and Hohle Fels are famous for their wealth of symbolic artefacts. Niven notes past suggestions—even raised by Hahn—that the small figurative artefacts found in Aurignacian deposits could have been the result of 'caching' by later Gravettian occupants of the Swabian Jura. However, given the relatively recent recovery of such finds from the basal Aurignacian level at Hohle Fels (Conard 2009), there is little reason to doubt the complex repertoire of symbolic material culture of the Swabian Aurignacian. Despite this, the first Aurignacian level at Geissenklösterle, level AH III, lacks portable, figurative artefacts (Bolus 2003, 155). There are also some differences in the technological characteristics of the assemblage. For these reasons, Hahn considered the earliest Aurignacian at Geissenklösterle to be typologically similar to the Protoaurignacian (Zilhão and d'Errico 1999, 34). As previously noted, this is no longer considered to be the case, and level AH III is not considered to have a typological affinity with the Early Aurignacian (Bolus 2003; Teyssandier and Liolios 2003). Artifact counts are relatively high, 622 n/m3 for Geissenklösterle and 1,558 n/m3 for Hohle Fels (Conard 2011, 232 table 19.1).

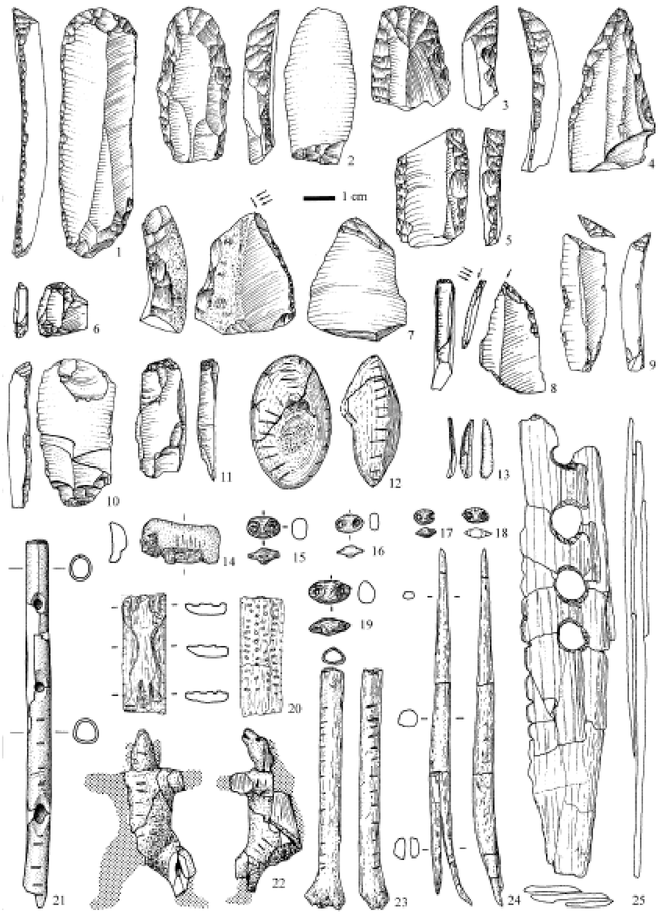

Figure 71. Representative artefacts of the upper Aurignacian horizon from Geissenklösterle. Copied from Conard and Bolus 2003, 352 fig. 11.

Middle Palaeolithic:

The chronology of Middle Palaeolithic of the Swabian Jura has been defined as a Swabian Mousterian with levallois reduction methods followed by a Micoquian followed by a leaf point/bifacial industry (Conard et al. 2012, 273). The later industry is also associated with caching of leaf points (ibid). The Middle Palaeolithic assemblages of Geissenklösterle and Hohle Fels are representative of the later Middle Palaeolithic (Figure 72). Artefact counts are lower compared to the Aurignacian, 70 n/m3 for Geissenklösterle and 89 n/m3 for Hohle Fels (Conard 2011, 232 table 19.1).

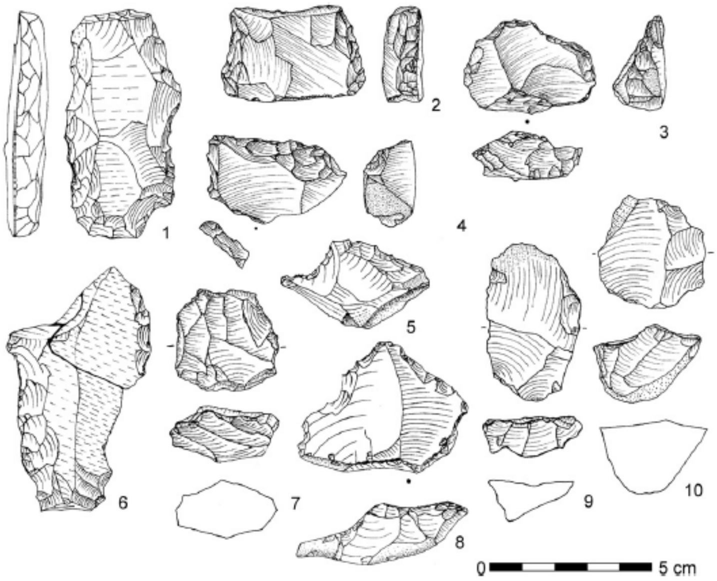

Figure 72. Middle Palaeolithic artefacts from Geissenklösterle and Hohle Fels. Copied from Conard et al. 2012, 238 fig. 2.

Synthesis:

1. The Magdalenian is poorly represented at both sites, but this may change in the case of Hohle Fels as excavations are still ongoing.

2. Bladelet production was a primary objective of reduction strategies during the Gravettian and Magdalenian with the latter having the highest microlithic component.

3. Despite the similarities between the Aurignacian horizons at Geissenklösterle and Hohle Fels, the former is unique in that the basal level does not demonstrate the diversity of artefacts seen in the basal level of Hohle Fels.

4. There is a significant difference in find densities between the Middle Palaeolithic horizons and Aurignacian horizons at both sites.

Material Sourcing

The sourcing of lithic materials at Geissenklösterle and Hohle Fels largely conforms to the regional synthesis as defined by Burkert and Floss (2006). According to this synthesis, source distances significantly increase from the Aurignacian to the Magdalenian within western Germany with nearly 100% of materials during the Aurignacian coming from 0-20km, increasing in distance during the Gravettian with ~90% of materials coming from 0-20km until the Magdalenian when sourcing becomes non-local with ~50% of materials coming from greater than 100km away. As with Primault's analysis of the Les Cottés assemblages, local is defined as lithic materials that have a site to source distance within 0-5km.

Magdalenian:

As previously noted, the Magdalenian at Geissenklösterle is poorly represented. However, Burket and Floss (2006) were able to complete a comprehensive sourcing analysis of lithic materials from the Magdalenian horizon at Hohle Fels. Local materials are the most common, 51.9%, while materials beyond 10km and even as far as 160km being fairly common (ibid, 331 fig. 3, 341 table 1).

Gravettian:

The site to source distances from the Gravettian horizon from Geissenklösterle shows a predominantly local pattern. Materials sourced within 5km are the most frequent followed by materials from within 10-20km while materials greater than 100km are very rare (Burket and Floss 2006, 340 table 1). Site to source distances record from the Gravettian horizon from Hohle Fels follows the same pattern. 68.8% of the materials comes from less than 5km away while ~28% comes with 10-20km, and materials greater than 100km are rare (ibid, 331 fig. 3).

Aurignacian:

Material sourcing during the Aurignacian occupation of Geissenklösterle was very local with 84.6% of the assemblage being represented by local material, Jurassic Flint (Burket and Floss 2006, 331 fig. 3). There are few sources further than 20km. Of those, Kiesseltuff from ~25km and Jasper ≥60km from the site are the most common (Hahn 1988, 106-8). Oddly, both sources are low quality materials (ibid). The location of exploited outcrops during the Aurignacian Indicates an east-west bias along the Danube fluvial system (ibid, 334).

Middle Palaeolithic:

Conard notes that material sourcing is primarily local (65-95% local materials) during the final Swabian Middle Palaeolithic. Like during the Aurignacian, Jurassic flint is the most commonly used raw material. Though very rare, materials over 20km are exploited, and there is evidence for sourcing of flint from Bavaria at distances of over 100km (Conard et al. 2012, 237, 234).

Synthesis:

1. Burket and Floss (2006) note that the greatest shift in sourcing during the Upper Palaeolithic occurs during the Magdalenian.

2. To an extent, this continues the trend established during the Gravettian when non-local materials become more heavily sourced.

3. The Aurignacian and Middle Palaeolithic appear to have similar sourcing patterns (Burket and Floss 2006). During these periods, local Jurassic flint accounts for the overwhelming percentage of utilized lithic sources.

4. The sourcing of long-distance materials during the Middle Palaeolithic from Bavaria suggests a similar east-west bias that continues into the Aurignacian.

Faunal Assemblages

As previously noted, there were many different potential agents that contributed to the accumulation of faunal remains in both Geissenklösterle and Hohle Fels. To this end, the faunal assemblages from both sites include carnivore remains such as cave lions, lynx, wolves, foxes, and hyenas (Münzel and Conard 2004a; b; Conard et al. 2012). This poses problems for assessing human subsistence behaviours during the Middle and Upper Palaeolithic occupation of the sites.

For example, Conard (2011) and Conard et al. (2013) argue that there was a significant shift in subsistence behaviour between Middle Palaeolithic and Upper Palaeolithic with the Aurignacian demonstrating widening of diet breadth to include fish, fowl, and most significantly small mammal game. Evidence for this actually provides a mixed signal. At Geissenklösterle, small game such as hare is not present in the Middle Palaeolithic or lower Aurignacian horizon (Münzel 2004, 74 fig. 1). By contrast, leporids are represented in the Middle Palaeolithic horizon at the nearby site of Kogelstein (Münzel and Conard 2004a, 239 fig. 12), but fox remains are also present, which may account for the presence of hare in the assemblage. However, as noted, fox and other carnivores are also present throughout the Upper Palaeolithic sequences of Geissenklösterle and Hohle Fels. Like Kogelstein, the presence of carnivores that specialize in hunting small game casts doubt on an anthropogenic origin for small game at Geissenklösterle and Hohle Fels.

I have therefore taken a conservative approach in the analysis of faunal assemblages from Geissenklösterle and Hohle Fels. For these reasons, I assume that reindeer, horse, and ibex/chamois (Zilhão and d'Errico 2003, 335; Banks et al. 2013a, 2[reply]) were the most likely species to have been exploited by both the Neanderthal and AMH occupants of Geissenklösterle and Hohle Fels. Two other species are common in both assemblages: cave bear and mammoth. There is very limited evidence for human predation of cave bear. The best evidence comes from cutmarks on cave bear skull fragments from the Gravettian horizon at Hohle Fels (Münzel and Conard 2004b, 878). Most likely, natural processes account for the presence of cave bear in the assemblages from Geissenklösterle and Hohle Fels. As previously noted, dating results suggest that mammoth bone beds were exploited as raw material sources rather than active hunting of mammoth.

Magdalenian:

In the Geissenklösterle assemblage reindeer are the most common species, accounting for 73%, followed by horse, accounting for 20%, and then ibex/chamois, which account for ~7% (Münzel and Conard 2004a, 228 table 1). The ranking is similar at Hohle Fels, but the percentages differ. Reindeer are the most common species at 52% of the assemblage while horse make up 43%, and ibex/chamois account for ~4% (Münzel and Conard 2004b, 879 table 1).

Gravettian:

In the Geissenklösterle assemblage reindeer are the most common, 52%, followed by horse at 33% and then ibex/chamois, which account for 14% (Münzel and Conard 2004a, 228 table 1). The Gravettian assemblage from Hohle Fels shows the greatest difference between the two sequences. The most common species in the assemblage is horse rather than reindeer, 53%, followed by reindeer at 40% while ibex/chamois make up the remainder, 8% (Münzel and Conard 2004b, 879 table 1).

Aurignacian:

In the Geissenklösterle assemblage, reindeer are the most common, 47%, but are followed very closely by horse at 46% while ibex/chamois account for 7% (Münzel and Conard 2004a, 228 table 1). In the Hohle Fels assemblage, reindeer are also the most common species, 56%, followed by horse at 36% and ibex/chamois at ~7% (Münzel and Conard 2004b, 879 table 1).

Middle Palaeolithic:

In the Geissenklösterle assemblage, reindeer are the most common species, 54%, while horse and ibex/chamois are almost equally represented at 21% and 25% respectively (Münzel and Conard 2004a, 228 table 1). Due to the ongoing nature of excavations at Hohle Fels, published information on the Middle Palaeolithic faunal assemblage from Hohle Fels is limited.

Synthesis:

1. Both Geissenklösterle and Hohle Fels generally show the same faunal pattern with increases in the frequency reindeer through the Upper Palaeolithic to the detriment of the percentage of horse.

2. This is probably a reflection of a general environmental trend, which suggests that the environment became increasingly more open and cold, tundra like.

3. The Gravettian assemblage is an important exception to the trend with horse being the most common species.

4. This may be reflective of slightly more temperate conditions during Greenland interstadial 8 or 9.

5. Horse also account for a significant portion of the Middle Palaeolithic assemblage, but by contrast, ibex/chamois also account for a substantial 24% of the assemblage.

6. The higher percentage of ibex/chamois sets the Middle Palaeolithic apart from the Upper Palaeolithic subsistence behaviours. This is in contrast to seasonality evidence that indicate an exploitation of prey during late winter during both the Middle and Upper Palaeolithic (Münzel and Conard 2004a).

Environmental Context

There are multiple lines of proxy data from both Geissenklösterle and Hohle Fels that provide environmental and climatic information: micro/macrofaunal, botanical/palynological, and sedimentological evidence. This substantial list is thanks to Hahn's focus on site formation processes Geissenklösterle, which have been continued at Hohle Fels by Conard and his research team.

One of the most significant palaeoclimatic events recorded in both sequences is the Les Cottés/Hengelo interstadial (Figure 73). This event marks both a break in occupation as well as the transition from the Middle to Upper Palaeolithic. Unlike Les Cottés, there is no record of a transitional assemblage following this event (*contra* Zilhão and d'Errico 1999). Rather, the Early Aurignacian follows the Les Cottés horizon at Geissenklösterle and Hohle Fels. This has been taken to suggest that local Neanderthal populations had been replaced by AMHs in the interval, bringing with them innovation typical of the Upper Palaeolithic (Conard and Bolus2006; Conard 2011; Conard et al. 2013). Chronologically, the Early Aurignacian occupation does not follow the Les Cottés/Hengelo interstadial as closely as the Chatelperronian does at Les Cottés itself. In fact, the Swabian Early Aurignacian follows at least 2,500 years later, indicating a significant gap in the record at the critical point when Neanderthal populations were to have been replaced by AMH colonizers.

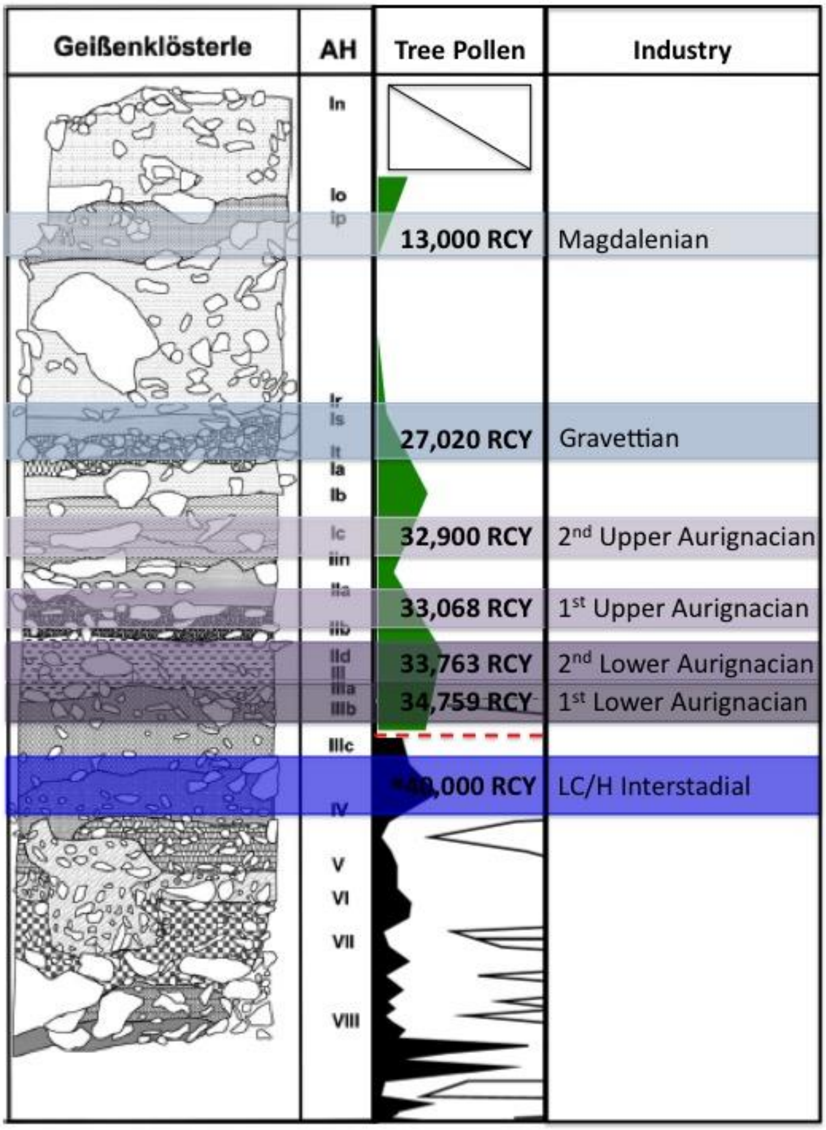

Figure 73. Environmental synthesis for Geissenklösterle. Stratigraphic profile from Conard and Bolus 2008, 888 figure 2, Lower graph, Pinus pollen from the Unterangerberg terrace from Starnberger et al. 2013, 29 fig. 8, Upper graph, frequency of Pinus from pollen and botanical fragments from the Hohle Fels sequence data from Riehl et al. 2014, fig. 5.

Magdalenian:

The environmental signal for the Magdalenian is a bit mixed. At Geissenklösterle, microfaunal evidence suggests a relatively dry environment (Hahn and Owen 1985, 62 fig. 1). Sediment suggests cold and wet conditions while macrofauna indicate post-LGM tundra-like conditions (Conard 2006, 318 table 1). The environmental signal at Hohle Fels indicates a relatively cold condition with evidence for cryoturbation (Riehl et al. 2014). However, sedimentological analysis suggests the environment was warmer and wetter than during the Gravettian, perhaps indicating sediment formation prior to the Bølling and Allerød.

Given the dating of the Magdalenian at both sites, formation then probably occurred after the Heinrich 1 event (Hemming 2004) and before the Allerød, perhaps during the Older Dryas.

Gravettian:

At Geissenklösterle, microfauna indicate a reduction in woodland and humidity to the favour of open landscape species (Hahn and Owen 1985, 62 fig. 1). Sedimentological analysis suggests moderate conditions for MIS2 while micro/macrofauna suggest a reduction in woodland from the signal of the underlying Aurignacian and an increase in tundra species (Conard 2006, 318 table 1). Botanical evidence from Hohle Fels suggests cold tundra-like condition common to the region prior to the to the LGM (Riehl et al. 2014).

Given dates and environmental indicators, the Gravettian horizon probably formed between Greenland interstadial 2 and 3 (Svensson et al. 2006, 3260 fig. 1), following the Denekamp interstadial (Riehl et al. 2014).

Aurignacian:

At Geissenklösterle, sedimentological analysis indicates a cool and humid environment at the start of the Aurignacian (Hahn and Owen 1985, 62 fig. 1). Moving upwards through the horizon, geological conditions suggest transition from a cold and dry environment toward moderate and mild conditions while micro/macrofauna suggest a woodland and boreal environment (Conard 2006, 318 table 1). At Hohle Fels, botanical evidence suggests a taiga environment with damp conditions transitioning toward a more tundra like condition at the end of the Aurignacian horizon (Riehl et al. 2014).

Given the dating range of the Aurignacian horizon at both sites, sedimentation probably occurred during Greenland interstadial 8 or 9 (Svenssion et al. 2006, 3260 fig. 1).

Middle Palaeolithic:

At this time, Geissenklösterle provides the most comprehensive information on the environmental context of the Middle Palaeolithic. Sedimentological analysis suggests warm and wet environment, fluxing between colder and moderate conditions (Conard 2006, 318 table 1). Microfauna and macrofauna suggests forest steppe transitioning into a boreal or partially wooded environment (Conard 2006, 318 table 1).

Given the moderate condition indicated by the environmental evidence, formation of the Middle Palaeolithic horizon probably occurred at the end of Heinrich 5 event (Hemming 2004), leading up to the Les Cottés interstadial.

Synthesis:

1. The general trend through the sequences at Geissenklösterle and Hohle Fels is a movement away from relatively temperate, wooded or boreal conditions toward an arctic, tundra environment.

2. The environmental signal is not substantially different between the Middle Palaeolithic and Aurignacian horizons.

3. The environmental conditions seem to change with the transition between the Aurignacian and Gravettian.

4. The surrounding environment during the Gravettian would have been open and cooler than that of the preceding periods.

5. This suggests different socioecological behaviours of the cervids exploited during the Gravettian as opposed to the cervid communities hunted during the Aurignacian and Middle Palaeolithic.

6. The environmental signal for the Gravettian is then correspondent with known pre-LGM conditions.

7. The environmental signal from the Magdalenian horizons suggests open, tundra like conditions following the LGM.

Discussion

The Aurignacian does not start with a 'bang' in the Swabian Jura. Despite the wealthy material culture found within the Aurignacian horizons at both Geissenklösterle and Hohle Fels, the very earliest evidence does not suggest much of a departure from behaviours already seen in the archaeological record of Western Europe. To this extent, the assemblage from level AH III at Geissenklösterle does not indicate anything more revolutionary than behaviours already present within the European transitional industries most famous of which being the Chatelperronian of central and southwestern France. However, the material culture of the Swabian Jura does appear to become more elaborate or at least their archaeological presence becomes more evident through the sequence at Geissenklösterle.

The hiatus in archaeological deposition during the Les Cottés/Hengelo interstadial obfuscates the ability to fully understand potential trajectories that resulted in both the potential extirpation of Neanderthals, Middle Palaeolithic communities. Likewise, the probable temporal gap between the formation of the Les Cottés sediment and the beginning of Aurignacian leaves an equally incomplete picture of the initial colonization of the Jura by AMHs. Interestingly, the lack of significant difference between Middle Palaeolithic and Aurignacian sourcing patterns may suggest that landscape usage did not change much between the final Neanderthals and first AMHs to inhabit Swabia.

There are, however, indications that fission-fusion patterns changed substantially during the Upper Palaeolithic as a whole. Like at Les Cottés, there is a negative relationship between the percentage of local material and more mobile prey, reindeer. However, the scale of this association appears less marked in the Swabian examples than within the Les Cottés sequence. Lithic sourcing in Swabian Jura is overall more local throughout the whole sequence. This is despite the fact that reindeer are the predominant species throughout both sequences with the exception of the Gravettian horizon at Hohle Fels.

However, environmental indicators at Geissenklösterle and Hohle Fels indicate greater ecological flux compared to the Les Cottés sequence. In the Swabian Jura, there is evidence for a large environmental transition from a boreal to an open tundra environment. This is not the case at Les Cottés, which suggest that human occupation of the site primarily coincided with open environmental conditions. The biggest break in the Swabian sequences is probably between the Aurignacian and the Gravettian. This results in an almost 20% drop in the percentage of local material. This is suggestive of a major change in fission-fusion behaviours between the Aurignacian and the Gravettian. Environmental factors are the most likely reason for the difference between the two periods (Burket and Floss 2006, 337). As the environment continued to transition into a cold steppe, the use of local material dropped even further during the Magdalenian.

Conclusion

This chapter provided an outline of the important archaeological sequences from Geissenklösterle and Hohle Fels. Together, these sites provide a comparative study area that due to their uniqueness from Les Cottés compliment the examination of fission-fusion behaviours during the late Pleistocene. As such, the previous chapter and this chapter have summarized the empirical information used in the following chapter to test the third and final test proposition: Neanderthal and AMH territorial areas did not respond in similar ways to environmental or ecological pressure.

CHAPTER 11

Testing the hypothesis part II: proposition 3

Introduction

In this chapter, the third and final test proposition, Neanderthal and AMH territorial parameters did not respond similarly to environmental or ecological pressures, is examined. To accomplish this, I employ both the fission-fusion heuristic model and statistical lithic sourcing model (chapter 7). The heuristic model enables an exploration of differences in fission-fusion organization between different site-level occupation events while the statistical analysis provides a truly robust test of the third proposition. The statistical test involves a multiple linear regression analysis. If the regression analysis shows a weak relationship between lithic sourcing and environmental factors or if the regression model shows one relationship associated with Neanderthals and another associated with AMHs, then the test proposition is upheld. Alternatively, if the linear model shows a strong correlation between lithic sourcing and environmental factors regardless of demic association, the proposition must be rejected.

In order to align information available for lithic sourcing patterns (Burkert and Floss 2006) and environmental information, I have synthesized the archaeological levels at the sites into cultural horizons, i.e. Middle Palaeolithic, Aurignacian, Gravettian, Magdalenian. Likewise, I have synthesized the lower and upper archaeological levels from stratigraphic level E at Les Cottés in order to align the site sequence with lithic material sourcing information from Primault (2003).

The sites of Les Cottés, Geissenklösterle, and Hohle Fels provide ample information that can be used to examine the fission-fusion behaviours of Neanderthals and AMHs under the framework of the heuristic model. However, lithic sourcing analyses at these sites pose a potential problem. Using only data from these sites will result in a bias in data pertaining to AMHs. This is because sourcing information is only available for the Mousterian, Chatelperronian, and first and second Early Aurignacian levels at Les Cottés; the Aurignacian horizon at Geissenklösterle; and, the Gravettian horizon and Magdalenian horizon at Hohle Fels. For this reason, I have supplemented the Neanderthal dataset with lithic sourcing and faunal data from two Quina Mousterian levels, 9 and 10, at the site of Les Pradelles. Before proceeding to the examination of the test proposition, the site of Les Pradelles is briefly discussed to provide general, contextual information about the site.

Les Pradelles:

Les Pradelles also known as Marillac and Les Pradelles à Marillac-le-Franc is an *aven* or sinkhole located in the Poitou-Charentes, within the same administrative region as Les Cottés. The site is well known for its hominin remains, which have been examined in several informative isotopic studies (Fizet et al. 1995; Richards et al. 2000; Bocherens 2009; 2011). Some of these remains show evidence of human modification, but whether this suggests cannibalism is currently unclear (Garralda et al. 2014). Of further note, incised bones, potentially symbolic artefacts, have been recovered from the Middle Palaeolithic horizon of the site (d'Errico et al. 2009, 29).

Comprehensively studied since the late 1960s, Les Pradelles contains eleven archaeological levels assigned to the Quina Mousterian (Costamagno et al. 2006). Thermoluminescence, faunal, and palynological analyses indicate that archaeological deposition occurred during MIS4 (Maureille 2008; Maureille et al. 2010; Mussini et al. 2011; Garralda et al. 2014). This fits well with the chronology of the Quina Mousterian in general (Costamagno et al. 2006). Levels 9 and 10 contain an entirely reindeer dominant faunal assemblage. Reindeer account for over 80% of both assemblages with horse and red deer composing the remainder of the assemblages (ibid, 472 table 2). This faunal pattern is reflective of Quina Mousterian assemblages in general (Discamps et al. 2011; Discamps 2014). Local materials overwhelmingly predominate, accounting for over 85% of both assemblages (Costamagno et al. 2006, 469 table 1). Interpretation of the lithic and faunal assemblages has suggested that Neanderthals used Les Pradelles as a short-term hunting camp for the processing of prey carcasses (Maureille et al. 2010).

A brief methodological explanation

As mentioned above, I employ heuristic and statistical analyses to examine how Neanderthals and AMHs adjusted the territorial sizes of their communities to adjust to environmental and ecological pressures. These analyses were outlined in the methods chapter (**chapter 7**). A short reiteration of the methods used in the heuristic model will help in the reading of the analysis results.

Heuristic analysis:

The heuristic analysis has been constructed in such a way as to enable an investigation of fission-fusion behaviours or modes that can be inferred from site level data. In order to do this, I use faunal assemblages contextualised within site-level and macro-level environmental information to reconstruct a picture of resource abundance and resource patterning. Ungulate species that constitute ~5%[2] or more of an entire assemblage are assumed to be the primary species predated by hominins and therefore a major indicator of ecological factors that would have placed the greatest pressure on Neanderthal and AMH communities in Western Europe.

For the primary species in an assemblage, I calculate kcal per km^2 and daily movement values into what I call a *cost budget*. The general values for kcal/km^2 and daily movement by species were presented earlier in the faunal synthesis (*see* **table 16** in chapter 7). In constructing a cost budget, I calculate a daily movement and kcal/km^2 value for the dominant species in an assemblage as a group, a *budget*. For example, open-landscape *R. tarandus* have a daily movement (**daily run**) value of 9 km and a kcal/km^2 value of 281010 kcal whereas *Bos* have a daily movement value of 3 km and a kcal/km^2 value of 2040000 kcal. An assemblage comprised entirely of open-landscape reindeer would therefore have a daily movement budget of 9 km and a kcal/km^2 budget of 281010 kcal while an assemblage that was 50% open-landscape reindeer and 50% *Bos* would have a daily movement budget of 6 km [(9 km 0.5) + (3 km 0.5)] and a kcal/km^2 budget of 1160505 kcal [(281010 0.5) + (2040000 0.5)].

To analyse the fission-fusion implications of the cost budgets, I place the daily movement values and kcal/km^2 values within a scatter-plot that is then superimposed over the heuristic model/framework (Figure 74).

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[2] The faunal assemblages at Geissenklösterle and Hohle Fels are treated a bit differently (*see* chapter 10). *C. elaphus* are included regardless of their total percentages because they are also utilized as an important environmental indicator when they co-occur with *R. tarandus*.

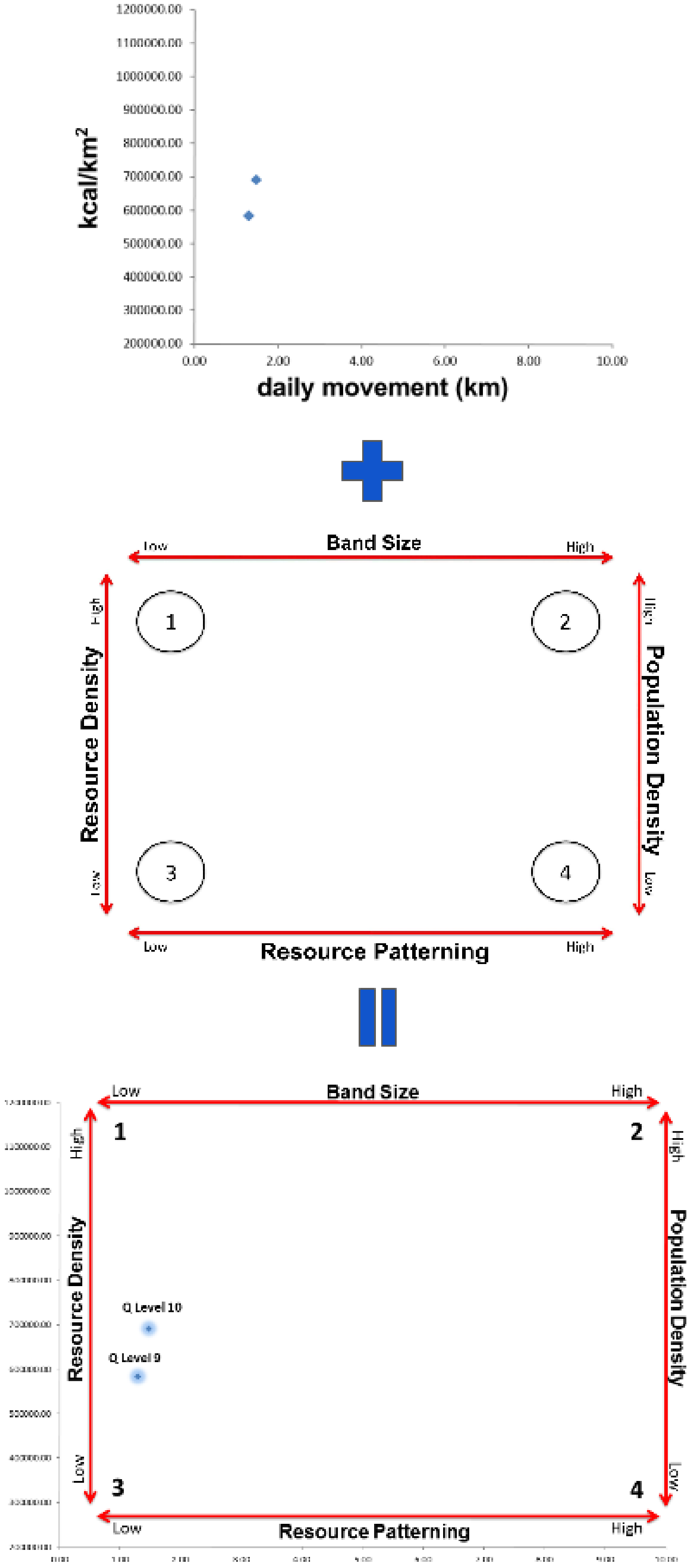

Figure 74. Placing the cost budget values within the heuristic framework. Levels 9 and 10 from Les Pradelles are used as examples.

In the plotting of the cost budgets, the daily values are placed on the X axis and the kcal/km^2 values are placed on the Y axis. All X and Y axes are set to the same scale in this chapter and any subsequent discussion. Under this framework, the values for daily movement are used as proxies for resource patterning and the values for kcal/km^2 are used as proxies for resource density. *Population* densities and *band sizes* are therefore inferred from this information (Figure 75).

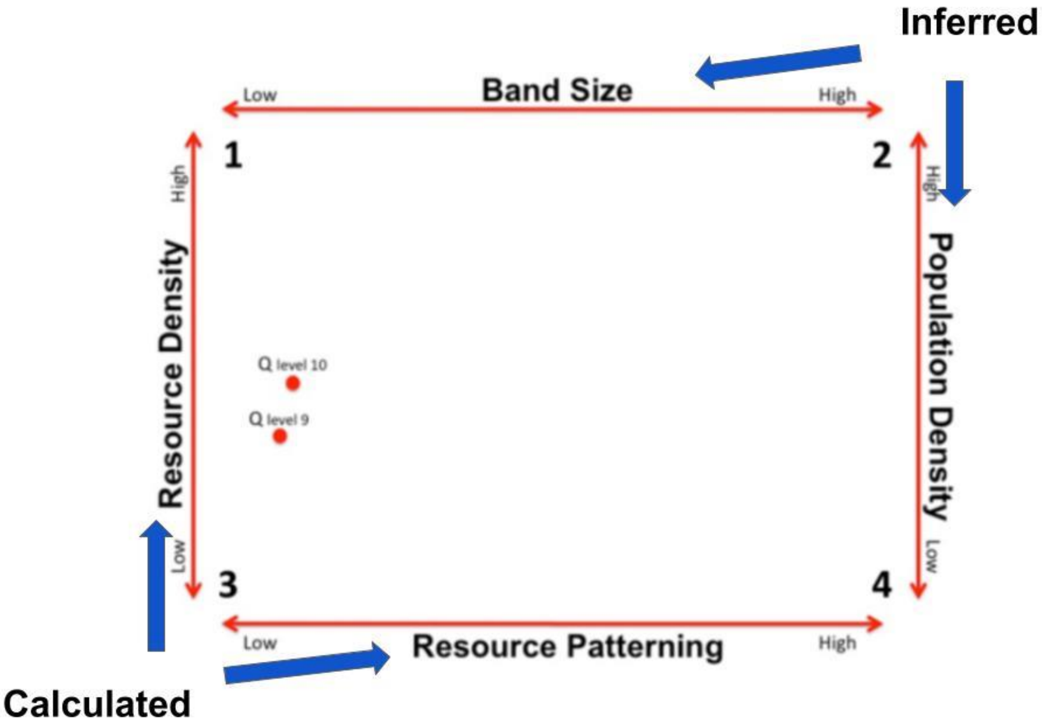

Figure 75. Known or calculated versus inferred information from the heuristic analysis

Chronological and Environmental settings

An accurate definition of the chronological and environmental context of the archaeological dataset is of great importance to the construction of both the heuristic and statistical models. The main reason for this is that ecological circumstances would have had the greatest effect on the spectrum of resources available to Palaeolithic human communities and, most importantly, on the socioecology of hunted prey. To this end, the socioecology of reindeer, the predominant species exploited at Les Cottés, Geissenklösterle, Hohle Fels, and Les Pradelles, is acutely affected by changes between tundra (open) and boreal (closed) environments. Figure **76** offers a visual schematic of the temporal and environmental setting of the archaeological dataset. The following sections provide a brief description of the ecological contexts and key environmental estimates for Les Cottés, Geissenklösterle, Hohle Fels, and Les Pradelles.

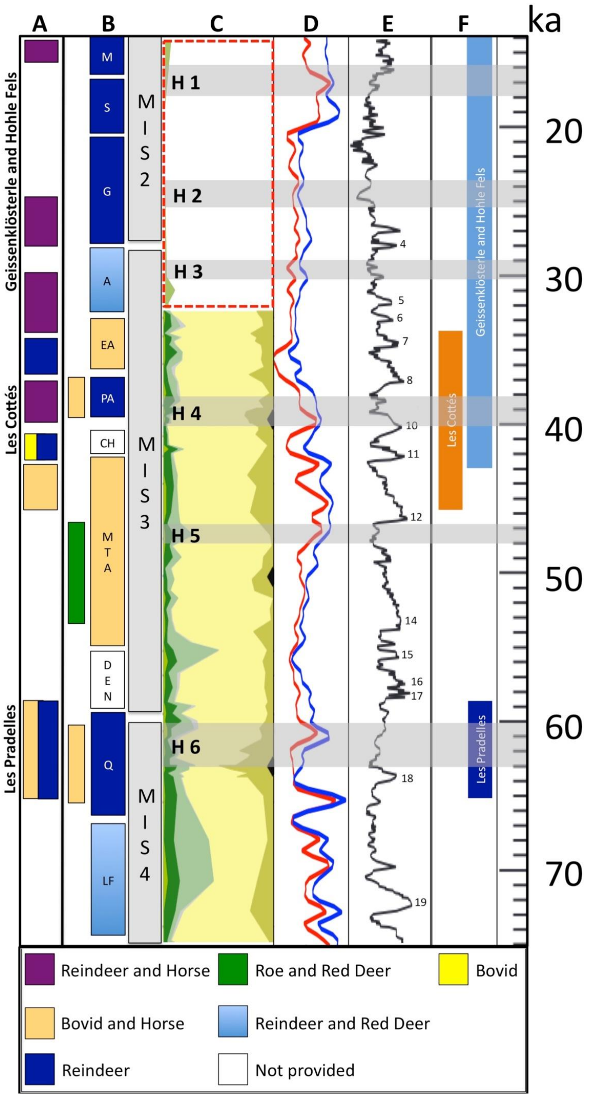

Figure 76. Environmental and cultural synthesis. A. Dominant fauna from each level used in regression model. B. General synthesis of faunal association per industry (Mousterian to Aurignacian) from Discamps 2014, 3 fig. 1 and (Gravettian to Magdalenian) Grayson and Delpech 2003: M = Magdalenian, S = Solutrean, G = Gravettian, A = Aurignacian, EA = Early Aurignacian, PA = Protoaurignacian, Ch = Chatelperronian, MTA, DEN = Denticulate Mousterian, Q = Quina, LF = Ferrassie Charentian sub-phase. C. Pollen diagrams, tree pollens in green and grass pollens in olive, upper diagram (in red box) from Riehl et al. 2014 fig. 5, showing *Pinus* from botanical/palynological analyses of Hohle Fels, bottom diagram from Fletcher et al. 2010, 2848 fig. 3 Calypso core MD04-2845, D. summer (red) and average (blue) temperature estimates from Grande Pile core sequence provided by Guiot, movement to the left indicates warming and to the right indicates cooling of air temperature, E. NGRIP interstadial curve from Sánchez Goñi et al. 2008, 1142 fig. 3, F. chronology of sites used in the regression and heuristic models.

Les Cottés:

The Les Cottés sequence demonstrates a progressive increase in the percentage of reindeer from the Mousterian to the Early Aurignacian levels (Table **31**). Micro-level, environmental indicators suggest that the site was occupied during cold, stadial periods that were most likely associated with open landscape conditions. This fits well with the macrofaunal spectrum of reindeer, bison, and horse.

Some aspects of the faunal record contradict an open environmental signal. For example, one red deer fragment (NISP = 1) was recorded from the Mousterian level from excavations between 2006-2010. Bouchud (1961) in his examination of the faunal material from Pradel's excavations does not record red deer in the Mousterian assemblage. Oddly, he does note the presence of one red deer dental fragment (MNI = 1) from the Aurignacian levels. Beyond analysing the Aurignacian on a horizon rather than on a level basis, Bouchud also appears to have included materials from the superimposed *Gravettian* assemblage into his analysis of the Aurignacian. Given this, there is no way to determine whether the red deer specimen recorded by Bouchud belongs to the Aurignacian levels, the currently undefined (Gravettian?) level, or the sterile sediments between the two.

Given that sedimentological analysis indicates that the human occupations of the site occurred during stadial periods (Frouin et al 2013, 193), which would have been unfavourable to *C. elaphus*, the red deer specimens probably do not relate to human activities at the site. More likely, the red deer specimens derived from the sterile Les Cottés sediments superimposed on the Mousterian level and the deflated Arcy interstadial sediments superimposed on the Aurignacian horizon.

Species	Aurignacian 2nd	Aurignacian 1st	Chatelperronian	MP
R. tarandus	271	301	41	45
Bos	3	17	20	36
Equus	4	63	11	16
total	278	380	72	97
%				
R. tarandus	0.97	0.79	0.57	0.46
Bos	0.01	0.04	0.28	0.37
Equus	0.01	0.17	0.15	0.16
Daily Run (km)				
9	8.77	7.12	5.13	4.18
3	0.03	0.13	0.83	1.11
3.5	0.05	0.58	0.53	0.58
Sum	8.86	7.83	6.49	5.87
kcal/km^2				
281010	273934.21	222219.75	160019.58	130365.46
2040000	22014.39	88578.95	566666.67	757113.40
1271914.286	18300.92	210870.00	194320.24	209800.29
SUM	314249.52	521668.70	921006.49	1097279.2

Table 31. Les Cottés *cost budget*.

Geissenklösterle:

As discussed in the previous chapter, the environmental signature and faunal spectrum at Geissenklösterle largely reflect one another. Sedimentological, botanical/palynological, and micro/macrofaunal analysis indicate that the ecological contexts of the Middle Palaeolithic and Aurignacian would have been similar. Red deer are present in very low frequencies in the Middle Palaeolithic and Aurignacian assemblages. Reindeer and red deer only overlap in boreal environments, as discussed in chapter 7. To this end, the Middle Palaeolithic and Aurignacian periods coincided with a largely closed, boreal environment while the Gravettian and Magdalenian periods coincided with an open and largely tundra-like environment. This implies that the socioecology of prey exploited would have been different between these two periods. Most significantly, the socioecology of reindeer from the Middle Palaeolithic and Aurignacian horizons should align with that of modern boreal reindeer while the socioecology of reindeer from the Gravettian and Magdalenian levels should align with that of modern tundra reindeer (Table **32**).

Species	**Magdalenian**	**Gravettian**	**Aurignacian**	**MP**
R. tarandus	11	183	247	53
E. ferus	3	116	242	21
Ibex/chamois	1	50	35	25
Total	15	349	523	99
%				
R. tarandus	0.73	0.52	0.47	0.54
E. ferus	0.20	0.33	0.46	0.21
Ibex/chamois	0.07	0.14	0.07	0.25
Daily Run (km)				
9	6.60	4.72	0.52*	0.59*
3.5	0.70	1.16	1.62	0.74
0	0.00	0.00	0.00	0.00
SUM	7.30	5.88	2.14	1.33
kcal/km^2				
281010.00	206074.00	147349.08	475093.80$^+$	150439.70$^+$
1271914.29	254382.86	422756.61	587598.85	269800.00
259449.75	17296.65	37170.45	17247.02	65517.61
SUM	477753.51	607276.15	1079939.68	485757.31

Table 32. Geissenklösterle *cost budget.* Reindeer daily run for the Middle Palaeolithic and Aurignacian is calculated at *1.1km (boreal reindeer), and kcal/km^2 for reindeer for these periods is calculated at $^+$475093cal *see* chapter 7, faunal synthesis.

Hohle Fels:

Hohle Fels largely fits the pattern described at Geissenklösterle. The exception to this is of course the Gravettian horizon where horse rather than reindeer are the predominant species. Likewise, horse also account for a higher percentage within the Magdalenian assemblage compared to that of Geissenklösterle. This may suggest a slight difference in seasonal usage of the two sites. However, such an assumption is unlikely given the recovery of foetal horse remains from the Gravettian and Magdalenian horizons at both sites (Münzel and Conard 2004b, 884). Regardless, the higher representation of horse in the Gravettian and Magdalenian horizons at Hohle Fels does not detract from the environmental description of these periods detailed previously for Geissenklösterle. Like Geissenklösterle, the environmental background during the Aurignacian was most likely closed and boreal-like while the environment would have been open during the Gravettian and Magdalenian (Table **33**).

Species	Magdalenian	Gravettian	Aurignacian
R. tarandus	78	73	34
E. ferus	64	96	22
ibex/Chamois	7	14	5
Total	148	183	61
%			
R. tarandus	0.52	0.40	0.56
E. ferus	0.43	0.53	0.36
ibex/Chamois	0.04	0.08	0.07
Daily Run (km)			
9	4.71	3.58	0.62*
3.5	1.51	1.84	1.27
0	0.00	0.00	0.00
SUM	6.23	5.42	1.89
kcal/km^2			
281010	147150.51	111893.07	266994.60^{+}
1271914.286	550016.99	668333.14	462514.29
259449.75	11394.75	19812.53	19297.92
SUM	708562.25	800038.74	748806.80

Table 33. Hohle Fels *cost budget.* Reindeer daily run for the Aurignacian is calculated at *1.1km (boreal reindeer), and kcal/km^2 for reindeer for this period is calculated at $^{+}$475093cal *see* chapter 7, faunal synthesis.

Les Pradelles:

The Quina Mousterian site of Les Pradelles presents a significantly different chronological and environmental setting compared to Les Cottés and the Swabian sites. Chronometric results and typological affinity indicate that the Les Pradelles archaeological sequence formed during MIS4. Palynological and macrofaunal evidence suggest a different ecological setting during MIS4 compared to those of MIS3 and MIS2. Unlike MIS2, there was a significant presence of *Pinus* throughout Western Europe, which was associated at times with spikes in *Abies* and *Picea* (Sánchez Goñi et al. 2008). These genera are apex boreal species (Richardson 2000, 15), suggesting a closed environment during most of MIS4. As discussed in chapter 7, in such environments, red deer and reindeer naturally overlap.

As previously mentioned, reindeer are the most common species in the faunal assemblages from levels 9 and 10 followed by bovids and equids (Table **34**). Importantly, small quantities of red deer have also been recovered from both levels. Given that the archaeological sequence dates to MIS4 and that reindeer and red deer are both present in the faunal assemblages, levels 9 and 10 probably formed during a time when the surrounding environment was a closed, boreal forest. In such contexts, the socioecology of reindeer are very different compared to those from the open tundra. Boreal reindeer move far less on a daily basis comparatively, but they are also significantly larger than their tundra counterparts. This means that resource density and patterning would have been very different for the Quina inhabitants of Les Pradelles compared to those of the final Aurignacian level at Les Cottés despite the dominance of reindeer in the respective assemblages.

Species		**9**	**10**
Bos		39	54
R. tarandus		800	477
C. elaphus		2	2
Equus		39	48
Total		880	581
%			
Bos		0.04	0.09
R. tarandus		0.91	0.82
C. elaphus		0.00	0.00
Equus		0.04	0.08
Daily Run (km)			
	3	0.13	0.28
	1.1	1.00	0.90
	1.1	0.00	0.00
	3.5	0.16	0.29
SUM		1.29	1.47
kcal/km^2			
	2040000	90409.09	189604.13
	475093.3333	431903.03	390050.81
	1891080	4297.91	6509.74
	1271914.286	56368.93	105080.70
SUM		582978.96	691245.38

Table 34. Les Pradelles *cost budget.*

Heuristic Model

As explained in chapter 7, the heuristic model has been constructed so that variances in fission-fusion organization, labelled fission-fusion modalities, can be examined. This model is not meant to be a hard test of the differences between the fission-fusion behaviour of Neanderthals and AMHs. Rather, it is designed to allow a descriptive and visual interpretation of fission-fusion patterns inferable from the dataset.

In order to model anticipated fission-fusion patterns, proxies for resource patterning and resource density are needed. As discussed previously, fauna probably accounted from a significant portion of the caloric resources available to peoples throughout the Palaeolithic while at the same time faunal assemblages provide the best evidence of past subsistence regimes during this period. For these reasons, I use the estimates for daily movement and calories per km^2 as proxies for resource patterning and resource abundance respectively.

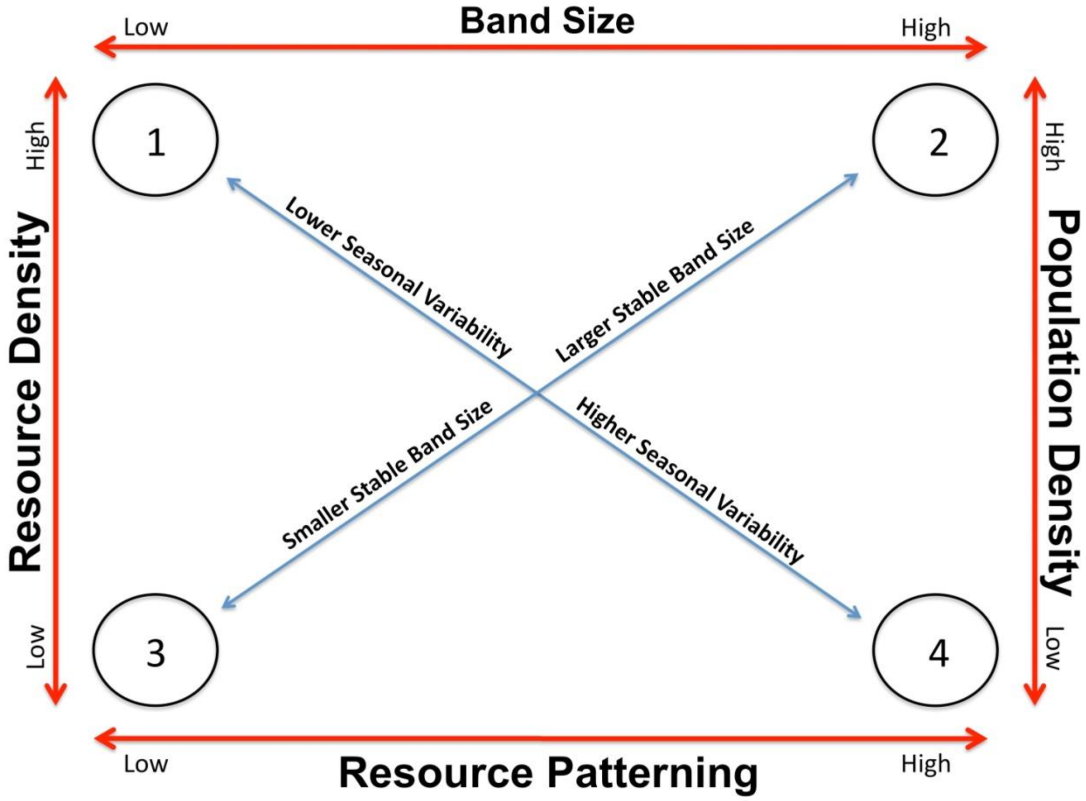

Figure 77. Heuristic model of hunter-gatherer band organization within a fission-fusion framework. After Ambrose and Lorenz (1990, 9 figure1.1).

Within the heuristic model itself, there are four stereotyped fission-fusion modalities that form endpoints on two spectrums of fission-fusion behaviour (Figure **77**). Under modality 1, band size is anticipated to be small to average (15-35 individuals) and stable, dietary diversity should be high, and raw material sourcing should be primarily local. Under modality 2, band size should be larger (>35 individuals) and may approach effective population size, dietary diversity should be high, and raw material sourcing should be local with some semi-local/neighbouring materials. Under modality 3, band size should be small (<25 individuals), dietary diversity should be moderate, but may be very low at the site/camp level, and raw material sourcing should be local, with some semi-local and non-local materials. Under modality 4, band size should be seasonally dependent with large bands (>35) splitting into smaller groupings (10-25 individuals) for large parts of the year, dietary diversity should be low, and sourcing of materials should be largely semi-local (>5km) with higher numbers of non-local materials.

Faunal and lithic material sourcing information from the dataset are used to assess whether the archaeological data fits with the model assumptions concerning dietary diversity and lithic sourcing regimes. This allows a general discussion of changes between raw material sourcing and dietary patterns. Band size is more difficult to assess. Find densities, assemblage sizes, and surface areas have been used to reconstruct Palaeolithic community sizes and demography (see Mellars and French 2011, Hayden 2012). As discussed earlier in the thesis, the palimpsestic nature of Palaeolithic sites problematizes the use of such information as proxies for occupation size (number of agents at a given site). The dataset is particularly subject to such issues as indicated by the problematic, chronometric results from Les Cottés and Geissenklösterle.

Les Cottés:

Plotting the levels from Les Cottés (Figure **78**) presents a linear trend that leads toward mode 4 during the final Aurignacian. All levels plot to the right side of the graph showing a progression from a moderate level of patterning to a highly patterned environment.

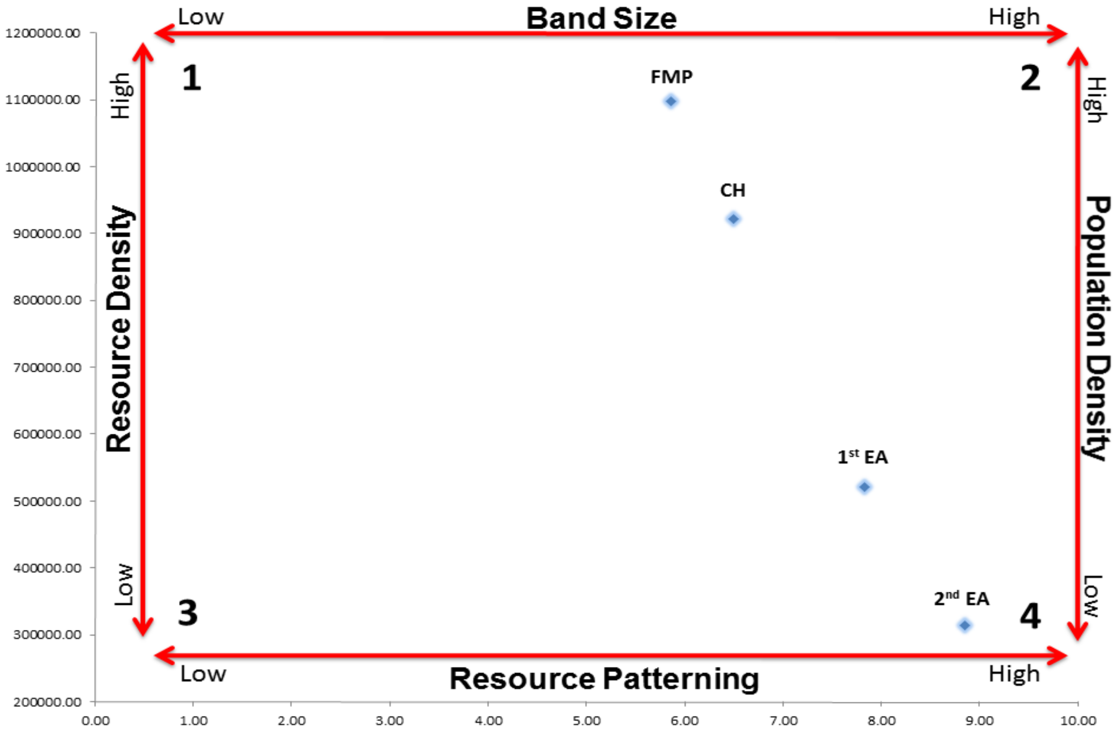

Figure 78. Fission-fusion heuristic model of the Palaeolithic sequence from Les Cottés.

As anticipated in the model, dietary diversity does decrease from the Mousterian to the final Upper Palaeolithic. This is indicated in both the number of species being exploited and the percentage of the assemblage represented by any one species. To this end, the level of diversity is never that great with the assemblages being only composed of equids, bovids, and reindeer. Nevertheless, there is a steady increase in the percentage of reindeer to the detriment of equids and bovids from the Mousterian to the final Aurignacian level where reindeer represent over 94% of the assemblage. This trend suggests a progressive reduction in resource densities/bioproductivity.

The sourcing of raw lithic materials also appears to fit well with the model expectations. The plotting of the levels suggests that material sourcing should include a greater number of non-local sourcing from the Mousterian to the final Aurignacian. Such a trend is clearly seen in the sequence with the steady decrease in the percentage of local materials from the Mousterian to the final Aurignacian level. Likewise, the presence of semi-local materials throughout the sequence, which account for a significant portion even within the Mousterian assemblage, accounts for the right-leaning placement of the levels on the graph.

Geissenklösterle:

Plotting the levels from Geissenklösterle (Figure **79**) produces a pattern that is more complex than that of Les Cottés. The Upper Palaeolithic portion of the sequence presents a linear trend from mode 1 to 4 while the Middle Palaeolithic falls toward mode 3. This suggests that the environmental contexts of the Mousterian and Magdalenian were less bioproductive compared to those of the Aurignacian and Gravettian. However, the environment during the Middle Palaeolithic would have been less patterned and therefore less predictable than during the Magdalenian. Further, the environments of the Middle Palaeolithic and Aurignacian would have been nearly equal in their low resource patterning, but the bioproductivity of the environment would have been fundamentally different between the two periods.

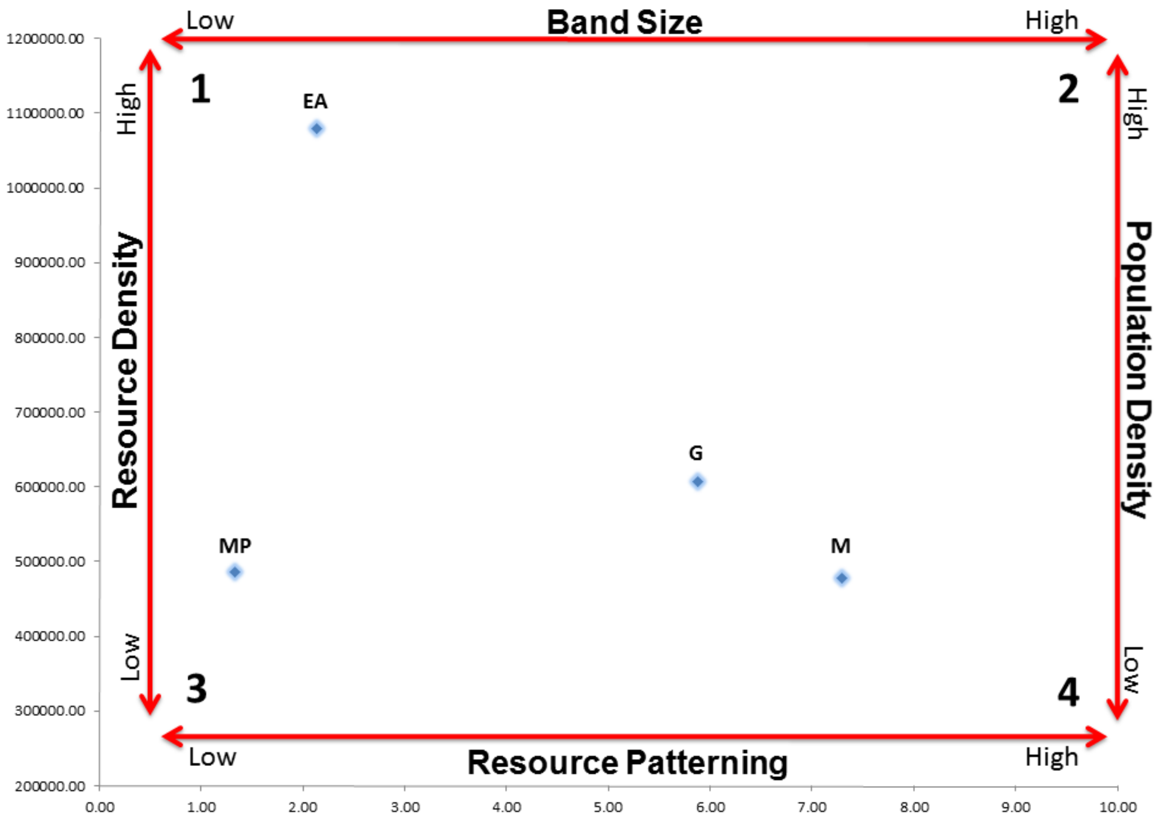

Figure 79. Fission-fusion heuristic model of the Palaeolithic sequence from Geissenklösterle.

The dietary diversity of the Middle Palaeolithic may be higher than the model expectations, while the Aurignacian seems to fit more comfortably within the mode 1 description. The Gravettian may also be a bit more diverse than anticipated, but the Magdalenian, like the Aurignacian, fits better with the model. What appears to throw off both the Middle Palaeolithic and Gravettian is the higher percentage of ibex/chamois. Ibex and chamois are known for their ability to live in low resource environments (Schweiger et al. 2015). Therefore, the higher percentage of ibex/chamois, despite making the Middle Palaeolithic and Gravettian dietary patterns seem more diverse, actually fits with the low resource density expectations assumed by the model for these horizons.

At Geissenklösterle, only the Aurignacian lithic assemblage has been thoroughly sourced. However, Burket and Floss (2006) suggest that sourcing patterns for the Gravettian and Magdalenian at Geissenklösterle are similar to those from Hohle Fels. As such, while the Aurignacian is very local (~85% of the assemblage), the Gravettian and Magdalenian become progressively non-local.

The model anticipates that the usage of local material should steadily decrease from the Aurignacian to the Magdalenian. This fits well with the assumed pattern of lithic sourcing. Likewise, the Middle Palaeolithic lithic assemblage is generally assumed to be even more local than that of the Aurignacian (Conard et al. 2012). This would also fit well with model given the plotting of the Middle Palaeolithic toward mode 3. Furthermore, Conard (2011) and Conard et al. (2006) argue that the Middle Palaeolithic occupation of the Swabian Jura was less intensive than that of the subsequent Aurignacian. This also supports the heuristic model, which indicates a significant difference in population densities between the Middle Palaeolithic and the Aurignacian.

Hohle Fels:

Plotting the levels from Hohle Fels (Figure **80**) presents a left to right movement from the Early Aurignacian to the Magdalenian. Given that all levels fall toward the middle of the vertical axis, there does not seem to be much of a change in resource density/bioproductivity in contrast to the trend from Geissenklösterle. However, like at Geissenklösterle, the results indicate an increase in resource patterning from the Aurignacian to the Magdalenian.

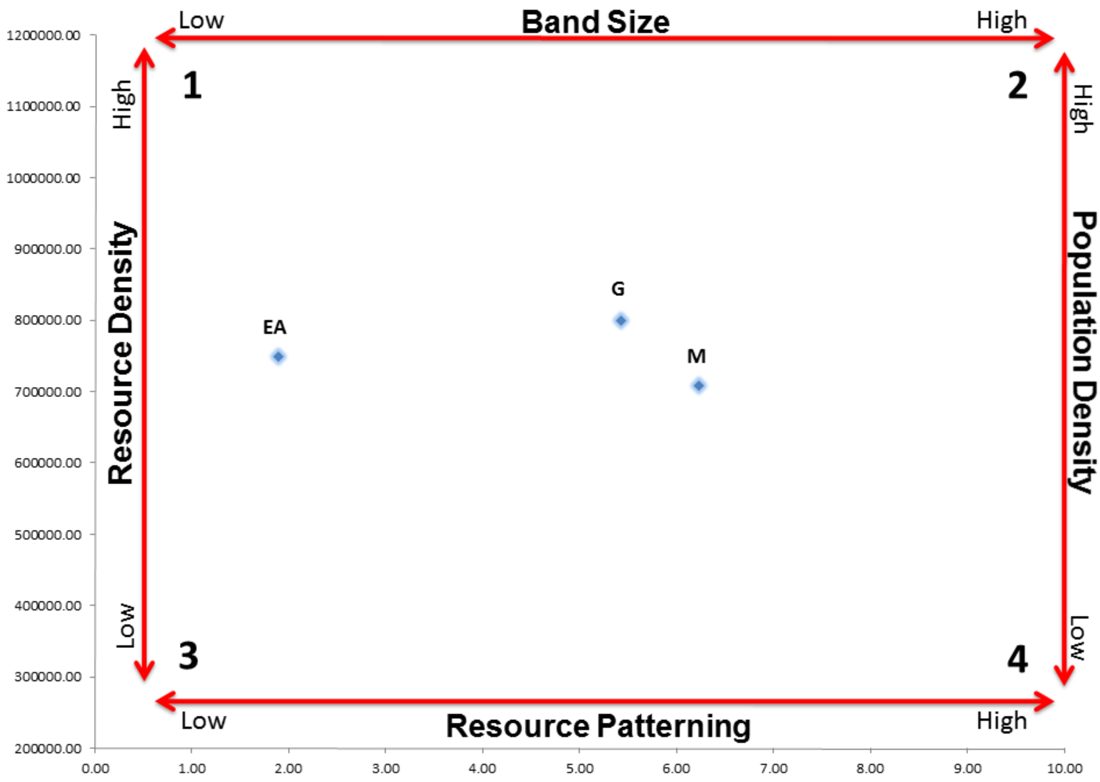

Figure 80. Fission-fusion heuristic model of the Palaeolithic sequence from Hohle Fels.

The different prediction for resource densities at Hohle Fels and Geissenklösterle may be due to differences in the timing of occupations. As noted previously, both sites appear to have been occupied during interstadials or periods leading/following warmer climatological events. The Aurignacian from Hohle Fels, however, appears to have occurred during a less bioproductive, perhaps less temperate, period. The Aurignacian at Hohle Fels therefore plots between the Middle Palaeolithic and Aurignacian from Geissenklösterle.

The faunal pattern at Hohle Fels does appear to match the model assumptions. As such, there is not much change in the diversity of dietary regimes between the horizons. However, reindeer dominate the Magdalenian and Aurignacian assemblages while horse are the most common fauna in the Gravettian assemblage. Despite the similarity in the Aurignacian and Magdalenian faunal assemblages, there is reason to believe that there were significant differences in the ecological circumstances of these periods. As previously discussed, the reindeer exploited during the Aurignacian were most likely part of a boreal ecology and therefore less patterned (lower daily movement) compared to the tundra like reindeer of the Magdalenian. So, despite equids dominating the Gravettian assemblage, the faunal pattern from the Aurignacian to the Magdalenian demonstrates a shift toward more mobile prey.

Likewise, lithic sourcing also appears to match model expectations. Material sourcing for the Aurignacian lithic assemblage is not clearly defined, but the material sourcing from the Gravettian and Magdalenian are better understood. As such, the movement in the plotting of the Magdalenian below and to the right of the Gravettian is reflected in the reduction in the percentage of local materials in the Magdalenian assemblage compared to the Gravettian.

The general trends in both faunal assemblages and lithic sourcing suggests a potential for increases in band size from the Middle Palaeolithic to the Magdalenian at Hohle Fels and Geissenklösterle. Interestingly, Burket and Floss note that the Magdalenian of western Germany suggests a “high degree of structural mobility and…long phases of residence in large base camps” (Burket and Floss 2006, 337).

Les Pradelles:

Plotting Levels 9 and 10 from Les Pradelles (Figure **81**) show both levels falling between modes 1 and 3. The plotting of level 10 suggests slightly more abundant and more patterned environmental conditions compared to level 9. This is the result of a greater inclusion of equids and bovids in the level 10 faunal assemblage.

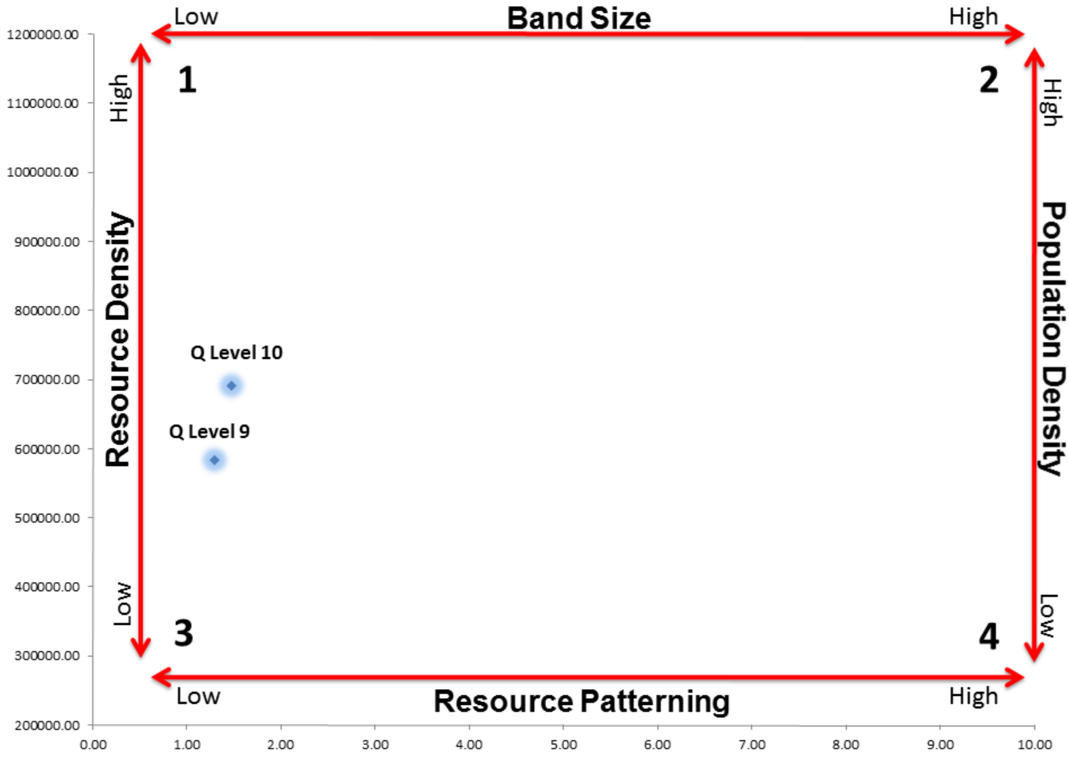

Figure 81. Fission-fusion heuristic model of the Palaeolithic sequence from Les Pradelles.

The almost monospecific pattern of the level 9 and 10 faunal assemblages fits well with model expectations. As such, the small increase in the percentage of equids and bovids in level 10 is reflected in the placement of this level above and to the right of level 9 on the graph. Lithic material sourcing also conforms to model expectations. To this end, the very local lithic sourcing regime (local material >85%) is anticipated by the placement of the levels between modes 1 and 3.

The plotting of levels 9 and 10 suggests a fission-fusion behaviour that falls within a spectrum of modes represented by the Aurignacian horizons at Geissenklösterle and Hohle Fels as well as the Middle Palaeolithic horizon at Geissenklösterle. The subsistence regimes of all five examples seem to have been directed primarily at the exploitation of boreal reindeer. In this spectrum of fission-fusion modes, movement on the graph falls within the vertical axis, indicating fluctuations in resource abundance within environments with low levels of resource patterning. As such, the movement along the vertical axis is the result of higher percentages of equids and bovids in some of the assemblages.

This fission-fusion spectrum is contrasted by another set of modes represented by the Les Cottés sequence and the Gravettian and Magdalenian horizons at Geissenklösterle and Hohle Fels. Within the latter spectrum, movement also falls primarily along the vertical axis. By contrast, this movement occurs within a significantly more patterned environmental context. This is because the primary focus of subsistence activities is largely directed at the exploitation of open-landscape/tundra reindeer. As such, movement along the vertical axis is largely a product of fluctuation in the exploitation of equids/bovids and reindeer. Unlike the former spectrum, the inclusion of these larger ungulates also results in greater horizontal movement. What is seen then in the plotting of the dataset is two spectrums of fission-fusion modes: the former relating to closed or semi-closed boreal environments and the latter relating to largely open, steppic/tundra-like environments. Importantly, Neanderthals and AMHs are not restricted to either spectrum.

Statistical Model

The heuristic model enabled a discussion of how environmental/ecological conditions would have affected the fission-fusion behaviour of the Neanderthal and AMH occupants of Les Cottés, Geissenklösterle, Hohle Fels, and Les Pradelles. This model, however, does not provide a robust test of whether Neanderthal and AMH territorial areas responded similarly to environmental/ecological pressures (proposition 3). In order to test this proposition, I use multiple linear regression to examine the relationship between the percentage of local lithic material (as the dependent variable) and prey daily movement/travel distance and calories per km^2 (as independent variables) in the dataset. I set the percentage of local material (0-5km) as the dependent variable because this data captures information relating to daily foraging areas. Faunal daily movement and calories/km^2 are set as the independent variables because these factors capture information on environmental conditions that should have had the greatest effect on past fission-fusion behaviour.

Linear regression model:

Out of the dataset, exact percentages of local materials are available for 9 levels/horizon, spanning the Quina Mousterian to Magdalenian (Table **35**).

Site/Level	Local Material	Faunal Daily Movement (km)	kcal/km^2
LC Mousterian	0.63	5.865979381	1097279
LC Chatelperronian	0.57	6.493055556	921006
LC Aurignacian	0.529	7.827631579	521669
LC Aurignacian	0.259	8.856115108	314250
Geis Aurignacian	0.85	2.136	1079940
HF Magdalenian	0.52	6.23	708562
HF Gravettian	0.69	5.42	800039
Les Pradelles 9	0.87	1.29	582979
Les Pradelles 10	0.95	1.475	691245

Table 35. Local material, faunal daily movement, and kcal/km^2 values available from Les Cottés, Geissenklösterle, Hohle Fels, and Les Pradelles. LC = Les Cottés, Geis = Geissenklösterle, HF=Hohle Fels.

Plotting this data within a multiple regression (Figure **82**) demonstrates a very strong correlation ($r^2 = 0.93$, $p = <0.00$) between the percentage of local materials and environmental conditions. I interpret this as indicating that Neanderthal and AMH territories were affected in kind by environmental stimuli.

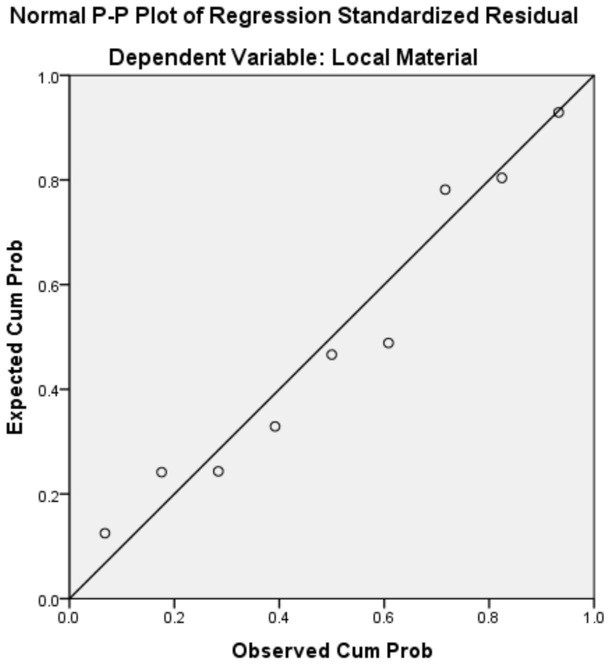

Figure 82. Cumulative probability of the relationship between local lithic material percentages and faunal daily movement and kcal/km^2 recorded in table 5.

The model results therefore, indicate that Middle and Upper Palaeolithic fission-fusion organization mirrors that of modern hunter-gatherers as understood within a band model framework. As such, the third proposition must be rejected. Interestingly, the proxy for environmental patterning, faunal daily movement (Figure **83**), produces the strongest correlation out of the two independent variables (**$r^2 = 0.912$, $p = 0.00006$**).

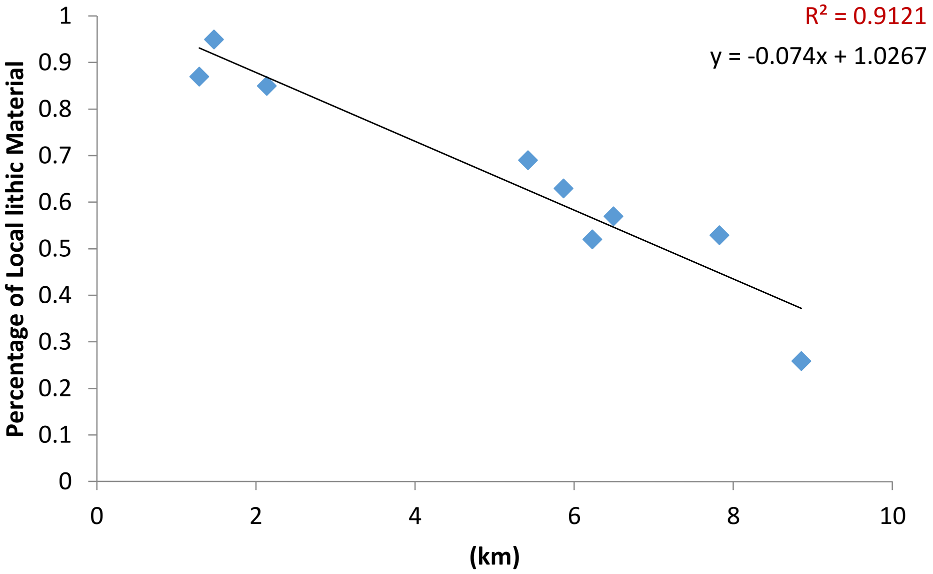

Figure 83. Linear relationship between the percentage of local lithic materials and faunal daily movements recorded in table 5.

In fact, the correlation between local material and faunal daily movement largely accounts for the strong confidence interval of the multiple regression model. This should be anticipated as local material, as defined in this thesis, must come within a 0-5km radii from the site of archaeological deposition. As such, faunal daily movement is a sound proxy for environmental patterning, as it captures information relating to site residency time. As such the speed with which prey move through the foraging area of a site dictates the residency time of the site occupants. Given the high confidence level of the correlation, the formula of the regression line can be utilized to make a predictive model for anticipated percentages of local material in late Pleistocene lithic assemblages.

Local material model

As discussed in the methods chapter, the MIS4 to MIS2 faunal synthesis compiled by Discamps (2014) provides a simplified database to create predictions about local lithic material usage during the late Pleistocene. Discamps' synthesis demonstrates significant turnovers in dominant species types from the Ferrassie Mousterian to the Magdalenian. There is, however, a general trend reflecting a reduction in large ungulates from the Mousterian to Magdalenian. The exceptions to this trend are the early Quina Mousterian, which is associated with boreal reindeer, and the middle and later (*evolved*) Aurignacian, which is associated with bovids and equids. I use the same cost-budget approach used for the heuristic and statistical models to generate daily travel estimates for the MIS4-MIS2 faunal synthesis (*see* Chapter 7). The daily travel estimates are then plotted (Figure **84**) using the linear formula from the regression model (y = 0.074x + 1.0267)

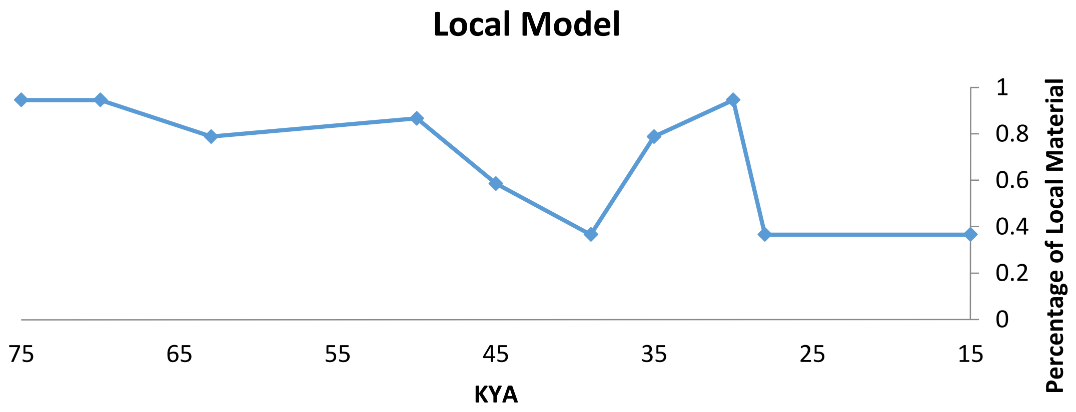

Figure 84. Predictive model of anticipated percentages of local lithic material sourcing from 75-15KYA.

The model predicts a much higher level of local sourcing during the Middle Palaeolithic compared to the Upper Palaeolithic. This fits very well with observations of lithic sourcing from Middle Palaeolithic and Upper Palaeolithic assemblages as discussed in chapter 6. This model strongly indicates that environmental conditions rather than technological or social differences between Neanderthals and AMHs account for the different pattern of material sourcing during the two periods. In fact, the results suggest that the raw material patterns were the result of the same band model behaviour expressed under different environmental circumstances. However, this model only accounts for local material patterns. It has been argued that differences in long distance sourcing between the Middle and Upper Palaeolithic are suggestive of fundamental differences in the social structure and behaviour of both demes (Gamble et al. 2011).

Modelling maximum lithic sourcing distances

To assess whether environmental forces structured maximum lithic sourcing patterns during the Middle and Upper Palaeolithic a macrolevel dataset is need that captures environmental information for these periods. Palaeoclimatic data from the Grande Pile bog provides such a dataset (*see* chapter 7 and appendix). As discussed in the methods chapter, to create a simple linear equation that can be applied to the Grande Pile data, I average the temperature estimates from 40,000RCY to 38,000RCY and 37,5000RCY to 36,000KYA, the end of the Middle Palaeolithic and onset of the Upper Palaeolithic, respectively. I then associate these variables with corresponding demographic estimates based on maximum material transfer distances recorded for these periods (Féblot-Augustins 2009). I use an estimate for late Mesolithic demography at 0.1 persons/km^2 (Milner et al. 2004, 13) to provide an estimate for Western European hunter-gatherer demography at current temperature conditions. These variables produce a simple linear relationship ($y = 0.0203x+0.1011$) that can be applied to the Grande Pile temperature estimates. Using Whallon's (2006) heuristic model, maximum sourcing distance estimates (Figure **85**) are produced under the assumption that Neanderthal and AMH shared a common band social structure.

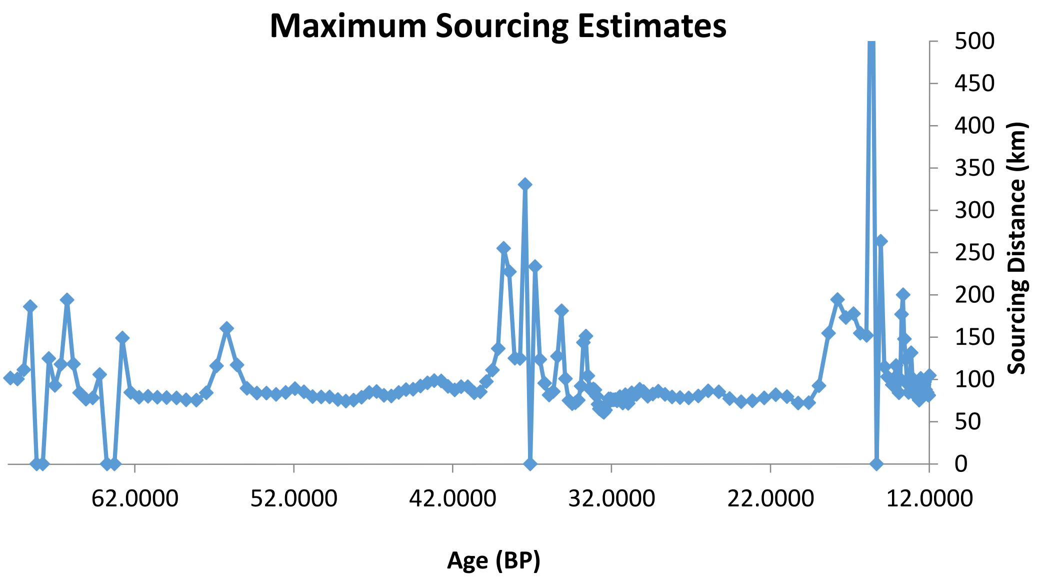

Figure 85. Predictive model of anticipated maximum lithic sourcing distances from MIS4-2.

The model shows several sharp, upward spikes. Some of these are paired with major downward spikes, as a result of the model producing null values. This pattern is an artefact of the model and most likely indicates episodes of extirpation. This is discussed further below (demographic model section).

Despite these anomalies, the visual representation clearly shows a sustained period of lithic sourcing beyond 100km during the LGM. Long distance sourcing is also recorded multiple times during the pleniglacial. By contrast, estimates for lithic sourcing distances beyond 100km are far less common within the Middle Palaeolithic timeframe. In fact, the model only makes three estimates beyond 100km for the Middle Palaeolithic that are not associated with extirpation spikes. These estimates cluster around 56-55KYA. By contrast, the model produces 25 estimates greater than 100km within the timeframe of the Upper Palaeolithic. It is important to remember that this model does not make any special cases for either the Middle or Upper Palaeolithic. It assumes that band sociality was in place during both periods, and that maximum lithic material transfers are representative of the movement of materials across *regional group* territorial areas. The structure of the model itself allows for the generation of demographic estimates, adding further context to the estimated trend in maximum sourcing distance.

Demographic model

The linear formula, y = 0.0203x+0.1011, produces demographic estimates from the Grande Pile data expressed in persons/km^2 (Figure **86**).

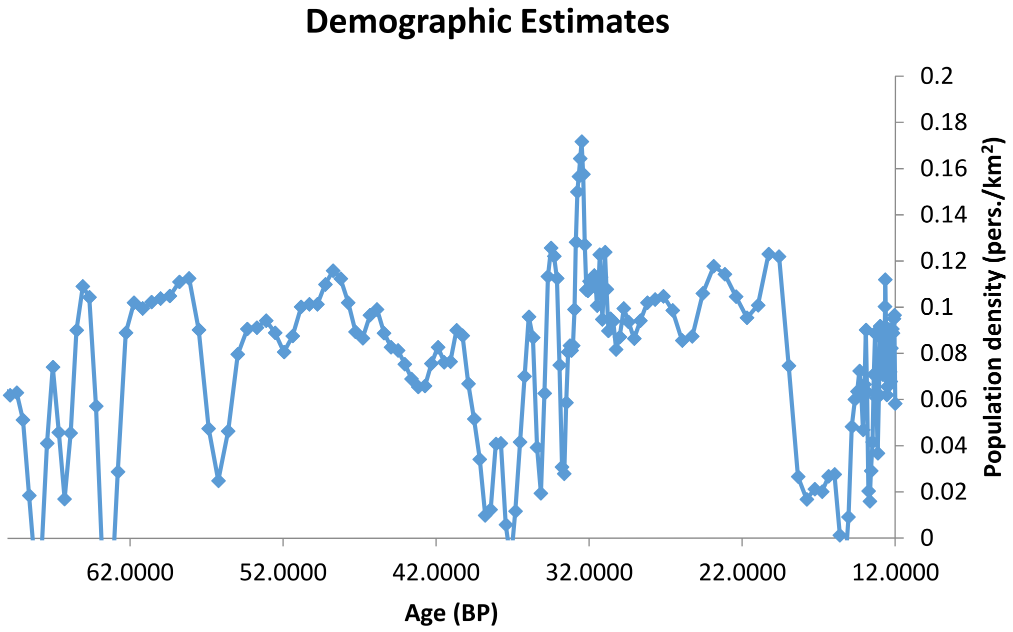

Figure 86. Predictive model of anticipated population densities from MIS4-2.

The model predicts two long, stable demographic periods between 70KYA and 12KYA. More significantly, the model estimates at least four extirpation events. The predictions of demographic estimates at 0 persons/km^2 are to blame for 'extirpation' spikes in the maximum sourcing distance model. Beyond predicting demographic extirpation during the Middle/Upper Palaeolithic transitions, the model also indicates that the transition was a prolonged, demographically unstable period. The periglacial is also predicted to have been a very unstable time, but in contrast to the transition, extirpation is not predicted. As with the maximum sourcing estimates, there are no special conditions for either the Middle or Upper Palaeolithic periods. As such, the environmental instability of the transitional period would have resulted in the extirpation of any band based human communities in Western Europe.

The maximum material sourcing and demographic models indicate that increases in material sourcing during the Middle and Upper Palaeolithic were products of the same process that underwrote percentages of local materials used at the site level. Just as changes in environmental carrying capacity affected the territorial and foraging areas of individual bands, these same environmental forces affected the territorial areas of *regional groups*, resulting in the predicted pattern of maximum sourcing distances during the Middle and Upper Palaeolithic.

Conclusion

This chapter examined the final test proposition: Neanderthal and AMH territorial parameters did not respond similarly to environmental or ecological pressures. The tests laid out in this chapter did not hold up the proposition, and it has therefore been rejected. Both the heurist and statistical models indicate that Neanderthals and AMH possessed a flexible band sociality capable of responding to environmental pressures. According to the *band model*, this capacity for flexible adaptation suggests that Neanderthal and early AMH social organization would have been similar to that of modern hunter-gatherers. The strong linear relationship between the percentage of local lithic material and faunal daily movement allowed for extrapolation of relationship into a predictive model for local material usage during the Middle and Upper Palaeolithic. Applying this equation to the MIS4-2 faunal synthesis compiled by Discamps (2014) predicted a predominantly local sourcing pattern for the Middle Palaeolithic while a greater use of non-local sources was predicted for the Upper Palaeolithic.

Given the strong correlation between environmental pressures (faunal daily movement) and site-level lithic sourcing patterns, an extrapolation of this relationship was applied to macro-level environmental data (Grande Pile) in order to make a predictive model of maximum sourcing distances from 70KYA to 12KYA. This model predicted sourcing of lithic materials from longer distances during the Upper Palaeolithic compared to the Middle Palaeolithic. The structure of the maximum lithic sourcing distance model enabled the creation of a demographic model spanning 70KYA to 12KYA. This model predicted several extirpation events within this timeframe. Importantly, the model indicated that the Middle to Upper Palaeolithic transition would have been one of the most demographically unstable periods during the late Pleistocene. The next chapter examines more fully the implication of these test results as well as providing a general discussion of the implications the *band model* holds for the understanding of Neanderthal and AMH sociality.

CHAPTER 12

Discussion

Introduction

In order to test the applicability of the band model to archaeological investigation I applied to the investigation of Neanderthal and AMH sociality during the late Pleistocene. This involved an examination of the proposition, that the fission-fusion behaviour of Neanderthals and AMHs were not comparable. Three supporting test assumptions (sub-propositions) were put forward: Neanderthal and AMH community sizes differed in size; Neanderthal territorial areas did not fall within the known range of those of modern hunter-gatherers; Neanderthal and AMH territorial areas did respond similarly to environmental or ecological pressures. The tests employed in this thesis failed to uphold the test assumptions, and therefore, the primary proposition must be rejected. Rather than supporting the assumption that the social structure of Neanderthals and AMHs were different, this thesis has shown that both demes possessed a flexible band structure comparable to those of modern hunter-gatherers as understood under a *band model.* As such, the *band model* has proven to be highly applicable to archaeological investigation, offering new and compelling interpretations of the Palaeolithic record.

The following is a general discussion of test results and what implications those results have in the understanding of Neanderthal and AMH sociality. The conclusions of the examination of each of the test propositions are discussed. This is followed by an exploration of the long distance sourcing and demographic model. The chapter concludes with a short discussion of how differences in fission-fusion modalities and historical trajectories may account for the general differences between the archaeological record of the Middle and Upper Palaeolithic.

Proposition 1

The examination of the group sizes of Neanderthals and AMHs was conducted within a social brain hypothesis framework. Two primary tests were conducted:

- a two-tailed t-test, comparing the cranial volume of the LCA of Neanderthals and AMH, *H. heidelbergensis*, with those of a modern human sample
- a regression analysis examining the relationship between orbital surface areas and palate breadth from *H. erectus to H. sapiens.*

The first test was conducted to examine whether a modern brain mass was an ancestral or derived trait shared by Neanderthals and AMHs while the second test was conducted to examine whether the large brains of Neanderthals and AMHs could have been the result of different selection, specifically whether the large brains of Neanderthals was an effect of selection on visual organs. The results of both tests suggest that a modern brain mass was selected for prior to the divergence of the Neanderthal and AMH lineages. According to the social brain hypothesis, the tests imply that the community sizes of *H. heidelbergensis, H. neanderthalensis, and H. sapiens* would have been comparable.

Though the tests conducted in chapter 8 do not indicate what selective processes led to the evolution of a modern brain mass, social dynamics must have played a role. According to the *band model*, it would be difficult to imagine an evolutionary trajectory that would allow for the emergence of a costly trait such as a modern brain mass without being directly related to or at least paired with the capacity to overcome the socioecological burden of the trait in question. To this end, it would have to be assumed that the capacity for flexible group cohesion best understood as a band-based sociality was in place prior to the divergence of the Neanderthal and AMH lineages.

Test Implications:

The implications of this are potentially numerous. As such, shifts in the archaeological record of the Middle Pleistocene warrant consideration. To this end, changes in the direction of technological and exploitative regimes seem of greatest importance. The Middle Pleistocene record presents a prime-age prey selection at Qesem Cave (Stiner et al. 2009, 13209), centralized pooling of caloric resources at Gesher Benot Ya'aqov (Goren-Inbar et al. 2002), emergence of Mode III lithic reduction at Purfleet (White and Ashton 2003), the development of discoidal core reduction at Gran Dolina (Vaquero and Carbonell 2003, 71), and shifts towards Mode III and even blade reduction at the Kapthurin Formation (Johnson and McBrearty 2010). Further, there is positive evidence for the systematic use of fire during the Middle Pleistocene (Roebroeks and Villa 2011). Evidence for controlled fire use is important beyond the potential implication of cooking (the release of nutrient resources the human body could not easily digest). Mastering fire would have significantly reduced total energetic expense.

Unlike clothing or the nesting behaviour of *Pan* (*see* Stewart 2011; Stewart et al. 2011), which only acts to conserve the loss of energy via retarding exothermic transfer, the consistent use of fire would have reduced one of the most important and energetically expensive roles of human metabolism, maintaining body temperature. The cognitive process behind controlled fire use should not be undervalued in this regard. Controlling fire does not just require that an agent has the cognitive capacity to learn the procedural steps of such an activity, but one that is capable of recognizing the inertial potential of metabolically inaccessible, cellulose rich, plant tissue. Given the complexity of controlling fire and that chimpanzees utilize environmental resources to conserve body heat, it seems probable that some form of body covering, tailored clothing or otherwise, became part of the repertoire of hominin adaptation during the Middle Pleistocene. Without such an adaptation, the energetic expense of living in even temperate environments, most of Eurasia, would have been too costly for hominin communities (Aiello and Wheeler 2003).

The question of whether modern social and cognitive capacities are rooted in the evolution of *H. heidelbergensis* has been asked previously, but is still considered an open-ended question (e.g. Gamble 2010, 23-4; Layton et al. 2012). For example, Layton et al. (2012) question whether Lower Palaeolithic material sourcing patterns are suggestive of a band sociality. They note that maximum lithic sourcing distances recorded for the Lower Palaeolithic are relatively short, 65km to perhaps 80km (Layton et al. 2012 *citing* Féblot-Augustins 1997). As such, they propose that this pattern could have been underwritten by a sociality that did not require the flexible dynamic of a modern band system.

However, as discussed earlier, the band sociality is a product of *exile from proximity* rather than *release from proximity*. Band size and band territorial areas (fission-fusion modes) are structured by environmental carrying capacity. Like other fission-fusion species, the ability for human communities to fission into smaller groupings, bands, has evolved as a means to deal with scramble competition. A sociality that is reflective of modern hunter-gatherers is one of dynamic flexibility in community cohesion. The question that should arise from the seemingly short maximum sourcing distance record for the Lower Palaeolithic is whether the environmental conditions would have allowed for a band-based community to live at such implied population densities.

As Layton et al. (2012) point out, the timeframe of *H. heidelbergensis*, particularly in Europe, occurred during moderate climatological conditions. For example, most skeletal specimens of *H. heidelbergensis* date to MIS11 (Dennell et al. 2011). This is also true for many well-documented European Lower Palaeolithic sites (Preece et al. 2007; Ashton 2008). MIS11 has been intensively studied as an analogue for contemporary Holocene conditions (Droxler and Farrell 2000; McManus et al. 2003; de Abreu et al. 2005; Tzedakis 2009; 2010; Rohling et al. 2010). In fact, MIS11 is considered to have been one of if not the warmest quaternary interglacial with average temperatures equal to +2°C warmer than present (Masson-Delmotte et al. 2010).

It is therefore difficult to contextualize the archaeological record of Middle Pleistocene Europe with a modern ethnographic analogue. As noted earlier, a conservative estimate of 0.1 persons/km^2 has been proposed for the Mesolithic. A population density of this level does not suggest the same territorial areas anticipated for much of the Middle of Upper Palaeolithic. Given the similarity of the MIS11 interglacial to the Holocene, a similar population density should be anticipated for much of the European Lower Palaeolithic record.

The long distance material formula presented in the previous chapter ($y = 0.025x+0.12$) predicts maximum sourcing distances of 67km to 80km when temperatures are 0°C to +2°C from present. Therefore, the model predicts the observed sourcing pattern for the Middle Pleistocene. This also suggests that material sourcing during the Middle Pleistocene follows the same trend observed within the latter half of the Late Pleistocene (MIS4 to MIS2) presented in the previous chapter. So even though site-to-source distances may be fairly short compare to later periods of the Palaeolithic, such a pattern would be wholly anticipated for a modern sociality, a band-based system, within the environmental contexts of the Middle Pleistocene.

It is important to note here the high altitude site of Gadeb, located in the Ethiopian high plains (de la Torre 2011). During Desmond Clark's excavation of the Gadeb in the 1970s, three Acheulian, obsidian handaxes sourced from a distance of 150km were recovered (Clark 2001). The Acheulian deposits from Gadeb date at least to the early Middle Pleistocene (Clark and Williams 1978, 23).

This evidence for long distance sourcing suggests that Middle Pleistocene hominins were capable of adapting to different environmental conditions through flexible group cohesion much like later Middle and Upper Palaeolithic peoples. The limited evidence, however, for this flexibility may have more to do with poor archaeological resolution than the capacity of *H. heidelbergensis*.

The limited nature of the Lower Palaeolithic record prevents attempts to analyse fission-fusion behaviours during this period to the same resolution as can be done for Middle and Upper Palaeolithic. For example, the record does not provide a regional archaeological context for important Lower Palaeolithic sites like Beeches Pit to the same degree that the cluster of Middle and Upper Palaeolithic sites along the Dordogne does for Le Moustier or Castenet. Instead, Lower Palaeolithic sites are often found in natural catchment areas, localities that have a greater capacity for archaeological preservation. These documented locations—such as terraces of riverine systems (Bridgland 2000; Bridgland et al. 2006)—create a fragmented but also monolithic picture of life during the Middle Pleistocene. These locations would have been areas of resource concentration where exploited materials would more likely have originated rather than been deposited (Hallos 2005, 159). This makes each site a *snapshot* in time, lending to an assumption that the LCA of Neanderthals and AMHs lived within a socially limited and immediate world (ibid).

Proposition 2

The analysis of this proposition relied on Whallon's (2006) heuristic model to assess whether lithic site-to-source distances during the Middle Palaeolithic and Upper Palaeolithic suggest territorial areas that would fall within the spectrum of those known for modern hunter-gathers. The analysis showed that while Middle Palaeolithic sourcing distances are often not as great as those of the Upper Palaeolithic both periods nevertheless suggest territorial areas common to modern hunter-gathers. Since territorial areas among extant hunter-gathers are dependent on ecological conditions, the most logical question is whether the differences in site-to-source patterns recorded for the Middle and Upper Palaeolithic were products of ecological forces as well. Further analysis is highly suggestive that this was the case.

However, this also means that there should be a degree of variability in sourcing patterns between the two periods as dictated by environmental conditions. This should be particularly true for site and regional levels. The following sections look at cases of this in Western and Central Europe.

Western Europe:

The Middle Palaeolithic record of Western Europe contains the well-known site of Champ Grand, located in the Massif Central, noted for its archaeological deposits that contain lithic materials sourced from locations greater than 240km from the site (Slimak and Giraud 2007). The site of Grotte Mandrin, located in the Rhone Valley, contains a Palaeolithic sequence of Neronian, Charentian (Mediterranean variant) Mousterian, and Protoaurignacian levels. The Neronian itself is a unique variant of the Charentian Mousterian with elongated levallois points (Soyons points) and microlithic elements (Slimak 2008).

Slimak's (2008) analysis of lithic site-to-source distances from these levels demonstrates a wide variability in lithic procurement (Figure **87**).

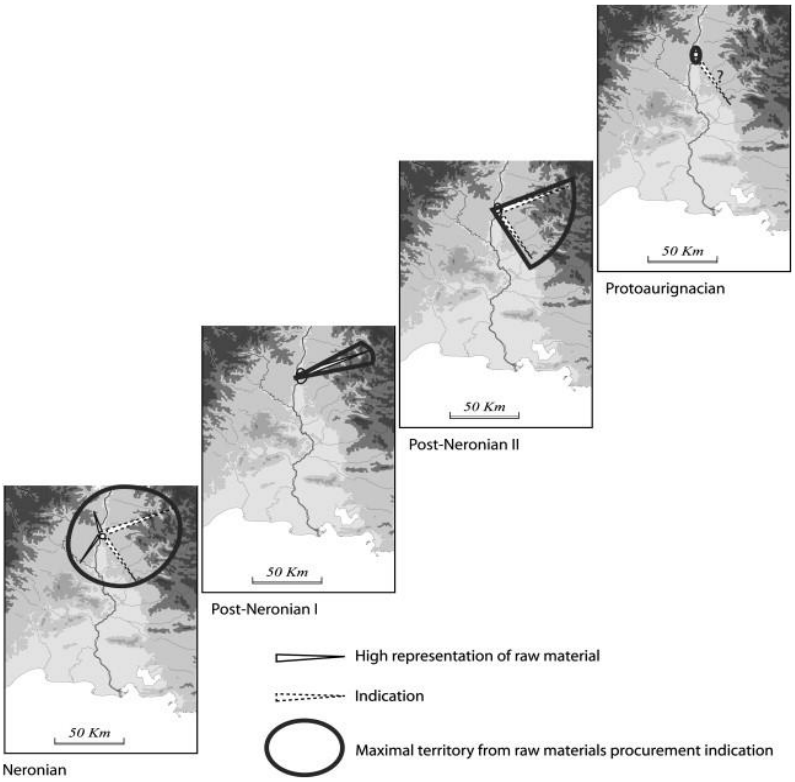

Figure 87. Changes in lithic sourcing patterns recorded in the Grotte Mandrin sequence. Copied from Slimak 2008, 2210 fig. 5.

The procurement of lithic material from the Nerionian horizon presents the longest procurement distances as well as the greatest number of resource locations exploited, presenting an elliptical sourcing area. Despite the presence of local lithic materials near the site, the assemblage is primarily composed of materials sourced from at least 20km from the cave (Slimak 2008, 2208). The Mousterian or *Post-Neronian* (I and II) horizon presents a different and predominantly local sourcing pattern. Non-local procurement is focused toward a single locality in the earliest portions of the horizon while two non-local sources were exploited in the most recent levels (ibid). The Protoaurignacian presents an equally limited sourcing pattern with some non-local materials potentially originating from south of the site. Overall, the Protoaurignacian assemblage is composed of high-quality, but very local materials (ibid, 2210).

The trends in lithic sourcing patterns between different occupation phases of Mandrin negates a simple assumption that territorial and logistical organization of the Middle Palaeolithic and Upper Palaeolithic can be easily stereotyped. Instead, a dynamic pattern of lithic sourcing is seen where raw material types and distances change from one period to the next regardless of whether the occupants of the site were Neanderthals or AMHs.

Central:

Sourcing of lithic materials over 100km is well documented within the Middle Palaeolithic of Central Europe (Féblot-Augustins 1993). The reason for the more frequent occurrence of long distance materials in the Middle Palaeolithic record of Central European compared to the West has been interpreted as an effect of environmental difference between the two regions (Gamble 1999; Sykes 2012, 74). Differences in territorial behaviour between regions should be anticipated under the band model as an effect of communities adapting to environmental differences in resource patterning and abundance. Féblot-Augustins (1993, 253) suggests the Central European record indicates seasonal movements by Neanderthals within a 10,000km^2 territorial range.

Comparison of the Central European record with territorial patterns of modern hunter-gatherers demonstrates that Neanderthals were capable of dynamic flexibility in their fission-fusion behaviour. The average territorial size for hunter-gatherer communities across six ecological divides (Layton and O'Hara 2010, 88-9 table 5.2) is ~4,560 km^2. As such, Central European Neanderthals were capable of maintaining social networks within a territory ~2.2X (10,000km^2/4,560km^2). If this territorial pattern were underwritten by a *regional group* social organization of ~500 agents, then the population of Central Europe during the Middle Palaeolithic would have been 0.05 person per km^2. To place this in a contemporary perspective, the observed global hunter-gatherer population density is ~0.17/km^2 (ibid). Féblot-Augustin's study suggests that Neanderthals were capable of maintaining social networks at an average population density 3.4X (0.17 per km^2/ 0.05 per km^2) less than that of modern hunter-gatherers. This indicates a remarkable capacity for dynamic group cohesion and mirrors the territorial patterns assumed for the Upper Palaeolithic of Western Europe (Djindjian 2009). However, as with Western Europe, lithic sourcing distances increased during the Upper Palaeolithic of Central Europe as well. This, as with the West, should be seen as an effect of LGM environmental conditions. Likewise, the increase in material sourcing distances between the Middle and Upper Palaeolithic is a general pattern rather than an absolute rule.

Figure 88. Map showing locations of Schwalbenberg, Wildsheuer III, and Lommersum. Map image from © OpenStreetMap, layer Humanitarian OpenStreetMap team.

As such, the record of the late Middle and early Upper Palaeolithic of the Rhineland demonstrates that sourcing distances were generally longer during the final Middle Palaeolithic. An example of this can be seen in the sourcing patterns recorded at the sites of Schwalbenberg, Wildscheuer III, and Lommersum (Figure **88**).

The open-air site of Schwalbenberg contains a late Middle Palaeolithic archaeological horizon, sometimes described as a transitional assemblage due to the occurrence of end scrapers and burins (Zöller et al. 1991). However, the presence of these elements along with leaf points (Burkert and Floss 2006, 334) is suggestive of a late Blattspitzen or Lincombian-Ranisian-Jerzmanowician assemblage both of which are assumed to be late Neanderthal products (Conard et al. 2006; Pettitt and White 2012). Interestingly, but not exceptionally for the local Middle Palaeolithic, the assemblage is composed predominantly of non-local material, a flint source 85km to the west, northwest of the site (Burkert and Floss 2006, 342 table 2). The material was more heavily exploited despite the presence of flint and siliceous slate within 1km of the site.

By contrast, the Aurignacian lithic assemblage from the site of Wildscheuer III is made entirely on lahn gravel, a material found within 1km from the site (Burkert and Floss 2006, 342 table 2). The Aurignacian from Lommersum presents a different pattern to that of Schwalbenger and Wildscheuer III. The lithic assemblage from Lommersum is primarily composed of Maasschotterflint sourced 30km to the northwest of the site (ibid). This material was also utilized at Schwalbenberg, but not as frequently despite being located only 70km from the site. Like Schwalbenberg, local lithic materials are available within 1km of Lommersum.

The sourcing patterns record at Schwalbenber, Wildscheuer III, and Lommersum suggest different mobility and territorial behaviours. The picture presented at these sites is one of bands adapting to local environmental conditions and larger ecological shifts during MIS3. Such a pattern should be anticipated if Neanderthals and AMHs shared a similar band sociality.

Proposition 3

Both the heuristic and statistical analyses suggest that Neanderthals and AMHs shared a similar capacity to adapt their territorial areas to environmental conditions. The strength of the regression model is highly suggestive of this. As such, the results of both analyses negate the test assumption. The application of the regression line from the statistical analysis to Discamps' (2014) MIS4 to MIS2 faunal synthesis indicates that a more local sourcing pattern should have been anticipated during the Middle Palaeolithic while a reduction in the use of local materials should be anticipated during the Upper Palaeolithic. Further, both the heuristic and statistical analyses indicate that closed versus open environments had the greatest impact on shaping territoriality during the late Pleistocene (Figure **89**). Changes from closed to open environments and the shift from an open steppe to tundra-like conditions during late MIS3 into MIS2 therefore account for the general differences in territorial and sourcing patterns between the Middle and Upper Palaeolithic.

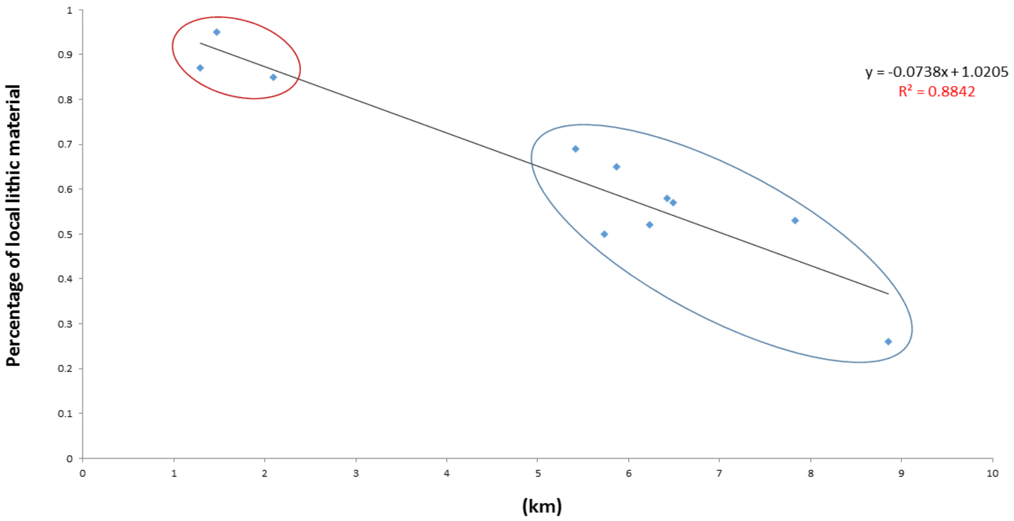

Figure 89. Clustering of lithic sourcing patterns in closed and open environments. Red = closed, blue = open.

Gamble (1999, 208) and Mellars (2002, 500) have both noted the association between increase in material sourcing distances and the shift from red deer to reindeer (closed to open environments) in southwestern France. Likewise, from the Middle to Late Pleistocene, Daujeard and Moncel (2010) observe that temperate and humid periods are associated with closed woodland environments that foster a faunal spectrum of roe deer, red deer, fallow deer, wild boar, and woodland rhinoceros. During dryer events within temperate periods where woodlands are demised, these species are sometimes associated with equids, steppe rhinoceros, giant deer, and aurochs. During glacial periods, which were highly pronounced during late MIS3 and MIS2, the environment was open, presenting a faunal pattern of reindeer, horse, bison, and wholly rhinoceros (Ibid).

This trend in environmental and faunal conditions is seen in both the dataset used in this thesis as well as the faunal synthesis. The heuristic and statistical analyses indicate that ecological change during the Late Pleistocene account for the difference in Neanderthal and AMH territorial behaviour. To this end, the material sourcing patterns of the Middle and Upper Palaeolithic are indicative of social territories structured by ecological circumstance comparable to those of modern hunter-gatherers.

Further discussion of the analyses and results:

Though the heuristic and statistical analyses suggest that open and closed environments account for a significant degree of variability in sourcing patterns, the fact that the Middle Palaeolithic dataset does not extend into a mode 4 type fission-fusion system (Figure **90**) may indicate different social capacities between Neanderthals and AMHs. This assumption may be likewise supported by the regression model, which indicates that non-local materials are never predominant in the Middle Palaeolithic sample population. However, this is a product of the dataset itself rather than differences between Neanderthals and AMHs.

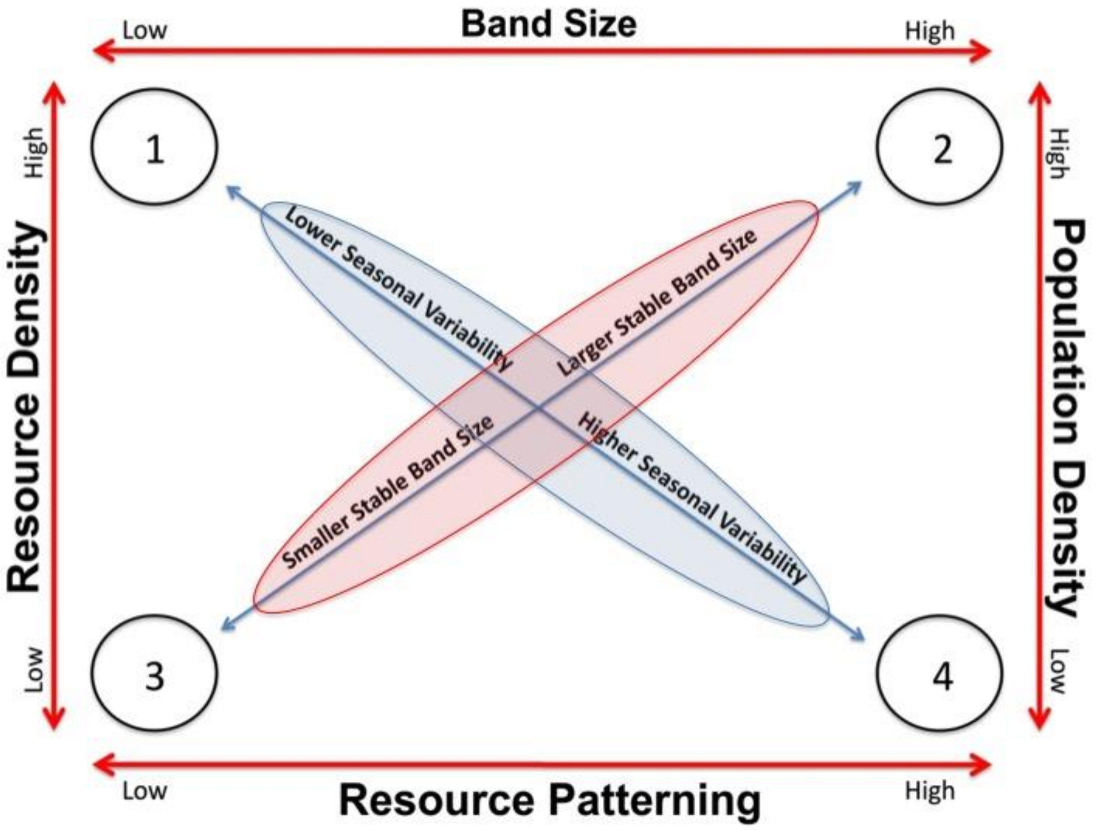

Figure 90. Potential differences in the spectrum of Neanderthal and AMH fission-fusion modes. Red = Neanderthal, blue = AMH.

To this end, the sourcing pattern of Schwalbenberg could be highlighted again with its dominance of non-local materials sourced from 85km from the site. Another important example is the Middle Palaeolithic site of Abri Rousseau, located within the Vienne, France, the same region as Les Cottés. Level II from Abri Rousseau formed during a cold climatological period when the environment was largely open (Bouchud 1959). The Mousterian assemblage from level II is typologically similar to the Mousterian level at Les Cottés, but by contrast, non-local material accounts for 76% of the assemblage (Primault 2003). Another potential Middle Palaeolithic site with a similar pattern is Lynford. Though there are lithic materials within the immediate vicinity of the site, these were not found with the lithic assemblage (White 2012). It is important to note in this context that reindeer and horse were the most likely targets of exploitation at Lynford (Smith 2012).

In fact, the more non-local lithic sourcing pattern observed in the Middle Palaeolithic record of the Central and Eastern European appears to be a product of similar environmental forces that produced the Upper Palaeolithic pattern in Western and Central Europe. For example, the well-studied (Kowalski et al. 1972; Madeyska 1988; Féblot-Augustins 1993; Patou-Mathis 2004; Madeyska et al. 2014) Middle Palaeolithic levels of Raj Cave, located in the Świętokrzyskie Region of Poland highlights this point. The *Eastern European Charentian* levels 4 and 6 from Raj show a similar sourcing pattern (Féblot-Augustins 1993, 232 table 4) to that of the Chatelperronian and first Aurignacian levels at Les Cottés as well as the Magdalenian horizon at Hohle Fels.

Féblot-Augustins (1993, 232 table 4) records that the percentage of local materials in levels 4 and 6 account for 58% and 50% of the lithic assemblages respectively. Such a pattern fits well with the faunal assemblages (Table **37**), which are predominantly composed of reindeer and horse. The site-level environmental signature (macro/microfaunal and pollen) is suggestive of an open, cold steppe (Patou-Mathis 2004).

Species	**4**	**6**
Bos	3.00	26.00
R. tarandus	23.00	81.00
C. elaphus	3.00	2.00
Equus	6.00	62.00
Total	35.00	171.00
%		
Bos	0.09	0.15
R. tarandus	0.66	0.47
C. elaphus	0.09	0.01
Equus	0.17	0.36
Daily Run		
3	0.26	0.46
9	5.91	4.26
1.1	0.09	0.01
3.5	0.60	1.27
SUM	6.87	6.00
kcal/km2		
2040000	174857.14	310175.44
475093.333	312204.19	225044.21
1891080	162092.57	22117.89
1271914.29	218042.45	461161.90
SUM	867196.35	1018499.45

Table 36. Cost Budget for levels 4 and 6 from Raj Cave. Data from Patou-Mathis 2004, 247 table 1.

Adding levels 4 and 6 to the regression model confirms that the sourcing and faunal pattern recorded at Raj Cave fits well with the associative trend between local material and fauna established within the existing dataset. Though the addition of these levels slightly reduces the r-square value (r^2 = 0.89), the addition of the Raj Cave sample strengthens the significance of the regression itself (p = 0.00002).

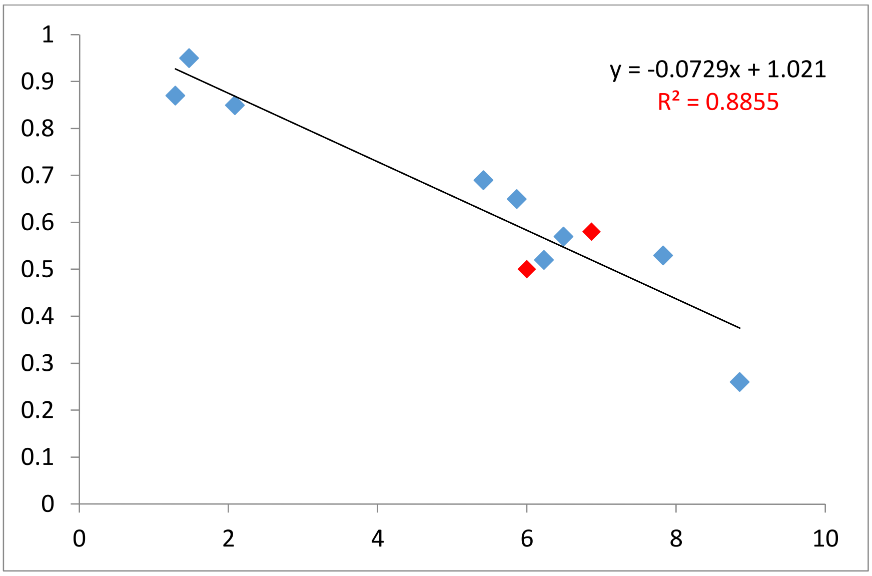

Figure 91. Updated local lithic material regression model to include data from levels 4 and 6 from Raj Cave. Levels 4 and 6 shown in red.

The regression model shows that the Raj levels fit comfortably within the 'open-landscape' cluster (Figure **91**), which further substantiates the observation that Neanderthal and AMH communities were equally capable of adjusting their social landscapes to environmental conditions as anticipated under the *band model*. Further to the point, there is no statistical difference ($p = 0.74$) in predicted versus observed results between the Neanderthal and AMH sample populations.

As should be anticipated under the band model, within closed and more moderate environmental contexts, sourcing patterns associated with AMHs are predominantly local. This is the case with the Aurignacian assemblage from Geissenklösterle. Likewise, the Mesolithic assemblages of the Ach Valley, which are associated with a closed wooded environment and a return of red deer, present a 96% to 100% local sourcing pattern (Kind 2006, 219 table 2).

Therefore, the Middle and Upper Palaeolithic records indicate that Neanderthals and AMHs were more than capable of long-term adaptations to specific ecological circumstances through the flexible cohesion of a shared band structure. In fact, it is this shared band sociality that produces both variability between and within the lithic sourcing patterns of the Middle and Upper Palaeolithic. Rather than seeing this as a difference between the two species, the heuristic and statistical analyses indicate that the general difference between the environmental context of the Middle and Upper Palaeolithic produced the respective sourcing patterns. It is precisely these environmental differences, which, when not framed within a band model framework, lend to the perception that Neanderthals and AMHs differed in their social behaviours and organization.

As presented in the previous chapter, site-level environmental and local material sourcing relationship was extrapolated to a larger environmental proxy (mid-summer temperature estimates from Grande Pile) in order to model patterns of long distance sourcing and demography from MIS4 to MIS2. Both models capture observed trends within the archaeological and genetic records that deserve further consideration.

Long distance lithic sourcing model

The long distance lithic sourcing model predicts that the sourcing of materials greater than 100km should be anticipated much more frequently after the Middle/Upper Palaeolithic transition. In fact, the model predicts twenty-five time-slices (not associated with extirpation spikes, *see* chapter 11) from the time range of the Early Aurignacian to the Magdalenian when sourcing distances should have exceeded 100km. By contrast, the model only predicted three time-slices (not associated with extirpation spikes) from 70kya to 40kya when sourcing distances should have exceeded 100km. The model does, however, predict a rise in sourcing distance after 40kya.

This model, like the local lithic material analysis, indicates that environmental pressures produced the differences seen in the pattern of long distance sourcing between the Middle and Upper Palaeolithic. The formulation of the model likewise assumes that the same band sociality, *regional groups* of 500 agents, underwrote the pattern of long distance sourcing from 70kya to 12kya. As such, the model implies that variability in long distance sourcing patterns are the result of past communities (Neanderthal and AMH) adjusting territorial areas in order to adapt to environmental conditions.

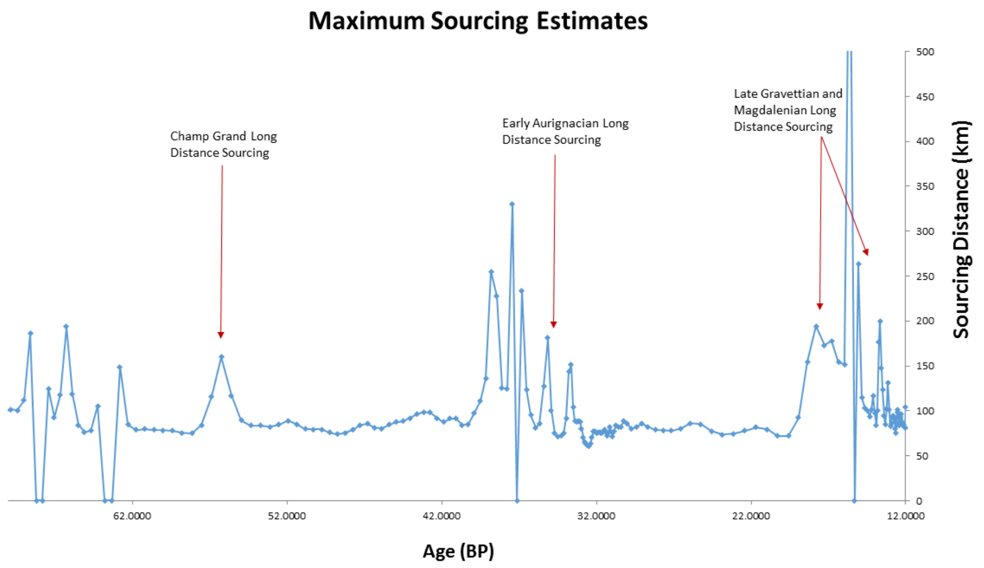

Figure 92. Maximum lithic sourcing distance model with highlighted observations.

The model predictions (Figure **92**) fit well with the observed pattern of long distance sourcing seen in the archaeological record. The three predicted time-slices for transfer distance beyond 100km for the Middle Palaeolithic cluster together around 56-55KYA. During this time long distance sourcing is recorded at the late Quina Mousterian site of Champ Grand (Kervazo et al. 2008, 69). In fact, site-to-source distances are recorded in excess of 200km (Slimak and Giraud 2007). The findings from Champ Grand have been seen as exceptional for the Middle Palaeolithic (Gamble et al. 2011). It is important to note in this regard that sourcing patterns during the UP of Western Europe rarely exceed 160km (Féblot-Augustins 1993).

The model predicts long distance sourcing for the earliest phases of the Aurignacian. This fits well with more recent findings of long distance sourcing during this period (Féblot-Augustins 2009). Though the prediction of only 25 time-slices during the Upper Palaeolithic may seem limited, this as well is mirrored in the archaeological record. For example, Féblot-Augustins notes that there are only 38 total occurrences (lithic artefacts, n = 38) that could be sourced to a raw material location greater than 100km from the beginning of the Chatelperronian to the start of the Magdalenian in Western Europe (2006, 451 CA comments to Brantingham). The model also predicts that the majority of long distance sourcing should occur towards the end of the Gravettian and continue into the Magdalenian. This is observed in the archaeological record with the majority of the long distance sourcing occurring during the Gravettian, Badegoulian, and Magdalenian (Féblot-Augustins, 2008).

Territorial and mobility implications:

Human communities during the Middle Palaeolithic and Upper Palaeolithic would have both been subject to set caloric requirements. These inescapable conditions play a major role in the shaping of hunter-gatherer fission-fusion behaviour, as the caloric requirement of a community translates into a minimum territorial parameter dependent on ecological and environmental circumstances, the patterning and abundance of resources. The circumstances of resource distribution would have therefore played a primary role in shaping both local and long distance material sourcing patterns in the archaeological record of the Late Pleistocene.

The study of local and long distance materials both match expectation of a shared band sociality by Neanderthals and AMHs. The local material analysis and long distance material model suggest a nuanced picture of raw lithic material acquisition during the late Pleistocene. As such, the pattern of sourcing shows that local and long distance sources were shaped by communities adjusting territorial areas to adapt to environmental circumstances. However, this process of adaptation creates two semi-distinct sourcing patterns. The first, usage of materials from 0-5km, seems strictly dependent on local availability of prey near a given site location while the second (long distance materials) appears to have been structured by larger environmental process such as overall carrying capacity (Figure **93**). These two are nevertheless intimately linked.

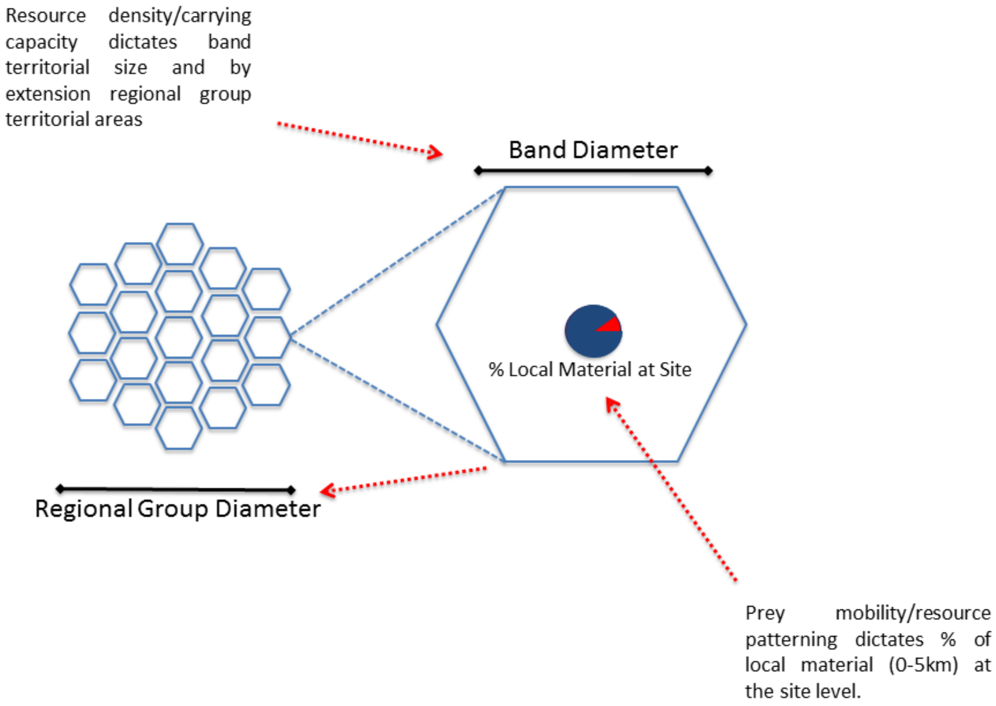

Figure 93. Heuristic model of lithic sourcing patterns within a band model social organization.

The interaction of these two forces, local and regional environmental conditions, was expressed in the fission-fusion heuristic model. Within this heuristic, a clear picture of how resource pattering and resource abundance affect the structure and mobility of bands emerged. The process of lithic sourcing could also be expressed in the form of a Lévy walk as explained further below.

Hunter-gatherer and animal foraging behaviours are often described as conforming to Lévy walk scenario (Raichlen et al. 2014; Perreault and Brantingham 2010; Brantingham 2006). This pattern of movement describes the relationship of optimal foraging movement within a randomly distributed environment (Ramos-Fernández et al. 2004). As such, the Lévy walk model does not perfectly reflect the effect of fission-fusion modalities on the pattern of lithic sourcing (Rhee et al. 2011), but it does provide a useful visual schematic of lithic material sourcing by mobile bands.

Within a band model framework, both Neanderthal and AMH communities would need to have established locations where resources would be centralized and shared among band members, a camp. At these camps, lithic materials would accumulate along with other exploited resources such as butchered fauna, creating the potential for an archaeological signature. Within a Lévy walk model, the distance between these camps form the walk length (*flight length*) while the camps constitute a cluster of shorter walks rather than a full pause in the length of a longer walk. Changes in resource patterning and abundance should create variance in the length of walks and the clustering of small walks around camps. As such, an increase in resource patterning coupled with a decrease in resource abundance (carrying capacity) should increase the length of long walks and reduce the clustering of small walks around camps.

This would create a double effect whereby the consumption of lithic materials during stays (short walks) around individual camps would decrease and the distances between (long walks) utilized raw material sources would increase, resulting in a higher portion of non-local and longer distance sources left at camp sites (Figure **94**).

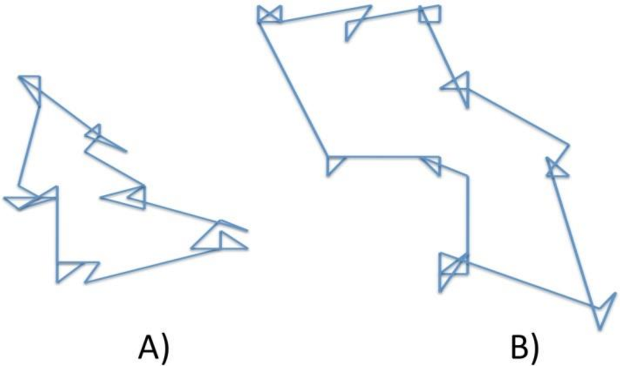

Figure 94. Lithic sourcing patterns as a product of Lévy walks. A) would produce higher rates of local material, B) higher rates of non-local material.

This pattern of band movement, as an effect of environmental forces, would dictate the total area of a band territory. To this end, the dynamic nature of these walks would also form the larger territorial area of a *regional group*, a composition of several bands. Though such a model may take into account more generalized conditions of band and regional group territoriality, it cannot account for the more dynamic nature implied in the fission-fusion heuristic model. As such, some environmental conditions would enable at times for large portions of the regional group to collapse onto the territory of one band.

Fission-fusion modes 2 and 4 would allow the potential for large band sizes. However, a mode 2 fission-fusion system implies larger stable bands with low mobility. Under such a condition, local materials should predominate. By contrast, the mode 4 fission-fusion system implies a greater flexibility in band formation on an annual basis. Under mode 4, bands would be anticipated to remain small and highly mobile for most of the year, but conditions of a highly patterned environment would allow for times throughout a year when large portion of the regional group could fuse together into a large band. Such a system would have higher potential for camps to act as a catchment for greater percentages of non-local and long distant lithic material resources. Changes in physical landscapes would have a compounding effect on this pattern.

-A Middle Palaeolithic example

The lithic material sourcing pattern at the Middle Palaeolithic sites of Grotta di Giganti and Grotta Mario Bernardini in southern Apulia may exemplify such a pattern. Non-local materials account for a significant portion of the lithic assemblages from the Giganti and Bernardini caves (Spinapolice 2012) while other sites in southern Apulia present a different pattern (Table **37**).

Site	Local	Non-local	Total	% Non-local
Bernardini	629	659	1288	0.51
Giganti	191	169	360	0.47
Uluzzo C	666	417	1083	0.39
Torre dell'Alto	194	46	240	0.19

Table 37. Lithic sourcing patterns recorded from Middle Palaeolithic sites in southern Apulia. Data from Spinapolice 2012, 685 tables 5 and 6.

Beyond the non-local pattern of these assemblages, jasper, flint, and quartzite materials were recovered from Grotta di Giganti sourced from at least 150km from the site (Figure **95**). Large number of non-local materials and long distance sources recorded at Giganti stands in stark contrast to the local sourcing pattern observed in the Middle Palaeolithic record of Italy in general (Spinapolice 2012 686).

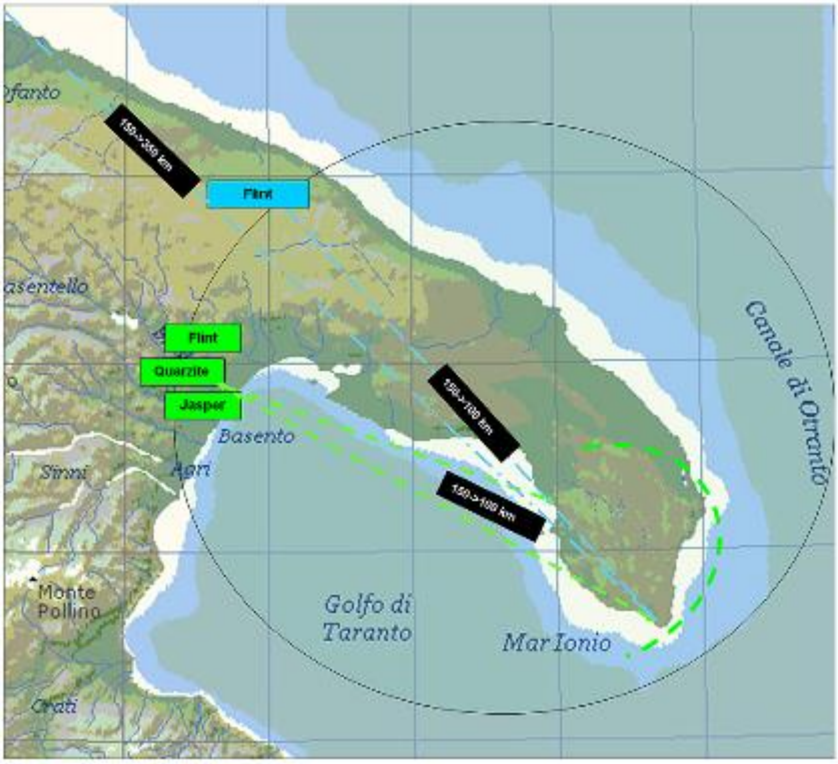

Figure 95. Map of maximum lithic sourcing distances recorded from Middle Palaeolithic sites in southern Apulia. Image copied from Spinapolice 2012, 686 fig. 7.

Spinapolice (2012, 687) argues that the lithic sourcing pattern recorded at the sites of southern Apulia could be reflective of a larger pattern of Neanderthal movement within a social area that extended well beyond southern Apulia. Under such a scenario, Grotta di Giganti and Grotta Mario Bernardini would have formed one end of an axis of north/south movement. Neanderthal groups would have travelled from the north to the Giganti and Bernardini caves before spreading out along the coast to exploit marine resources, predominantly shellfish (Milliken 2007, 338), on a seasonal basis. This pattern resulted in the exceptional sourcing distances record Grotta di Giganti.

The physical landscape along with the patterning and abundance of resources therein produced the unique sourcing patterns recorded in southern Apulia. As such, the pattern likely records band movement and aggregation within a *regional group* that extended throughout much of Apulia. The location of Grotta di Giganti therefore lied at the southern extreme of the territory of a *regional group*. Removed from the obvious landscape restrictions of southern Apulia, a site to source distance of 150km or more would suggest a large territorial area of 12272km^2 according to Whallon's heuristic model (2006). However, the true territorial area of a *regional group* suggested from the southern Apulia record would be closer to 4500-7500km^2 with a marine regression of 0 to 5km.

The pattern of lithic sourcing during the Middle Palaeolithic of southern Apulia demonstrates how both physical geography and fission-fusion adaptations to resource patterning and abundance can exaggerate sourcing distances. To this end, bands moved from the northern interior of Apulia to the southern coasts to exploit a highly, seasonally patterned but highly abundant resource, edible marine shellfish. This movement resulted in the transport of materials from very long distances and from multiple sites. The long distance nature, percentage, and frequency of the material sourcing recorded at Grotta di Giganti and Grotta Mario Bernardini was a product of the inhabitable landscape, abundance, and patterning of resources within shaping the territory of a *regional group* in which bands migrated on a north/south axis. In reality, the transfer of long distance materials recorded at these sites does not need to equate to a larger territorial area than would be anticipated for the rest of the Italian peninsula during the Middle Palaeolithic. Material sourcing during the Upper Palaeolithic should be anticipated to be more non-local due to decreases in carrying capacity and increases in resource patterning. Such a process may have become exaggerated at the close of MIS3 continuing through MIS2 due to the reshaping of the inhabitable landscape as a product of larger scale ecological deterioration.

-A similar process for the Upper Palaeolithic

It has been noted (Djindjian 2009; Bruxelles and Jarry 2011) that Upper Palaeolithic communities were driven into "narrow valleys" (Bruxelles and Jarry ibid, 546) during the advance of the last glacial, changing the characteristics and shape of previously stable human geographies. The reshaping of the inhabitable landscape was coupled with a large-scale ecological deterioration of Western Europe. These environmental forces would lead to an increase in minimum territorial areas of band-based communities, creating a knock-on effect that reshaped settlement dynamics and material sourcing patterns.

Therefore, as communities became more restricted to a set of geographical features, such as small valley systems, community territories would take on the spatial characteristics of these confined environments. A two-dimensional/overhead view of lithic site-to-source distances that would result from such a system would artificially inflate the size of territorial areas implied within such a framework. This problematizes the use of lithic material sourcing patterns recorded at Palaeolithic sites when viewed from a top-down, or bird's eye view. Gamble et al. (2005, 210) caution that such an approach does not capture the social landscape of past hunter-gatherers, which would have been based on an "itinerary" of paths and trails. To this end, the use of Whallon's heuristic model (2006) may be usual in the examination of general differences in social territorial areas, but may not suffice in specific cases. The seasonal movement of modern reindeer herders exemplifies the problems inherent in such an approach.

Nenet and Komi communities drive their reindeer herds between winter and summer grazing grounds over paths that can extend up to 450-500km, averaging in some cases 1000km of travel in one year (Dwyer and Istomin 2008, 526). However, these distances do not equate to a diameter of a super large territorial area. Rather they reflect very restricted movements over long distances in territorial areas within an acute north to south orientation (Figure **96**).

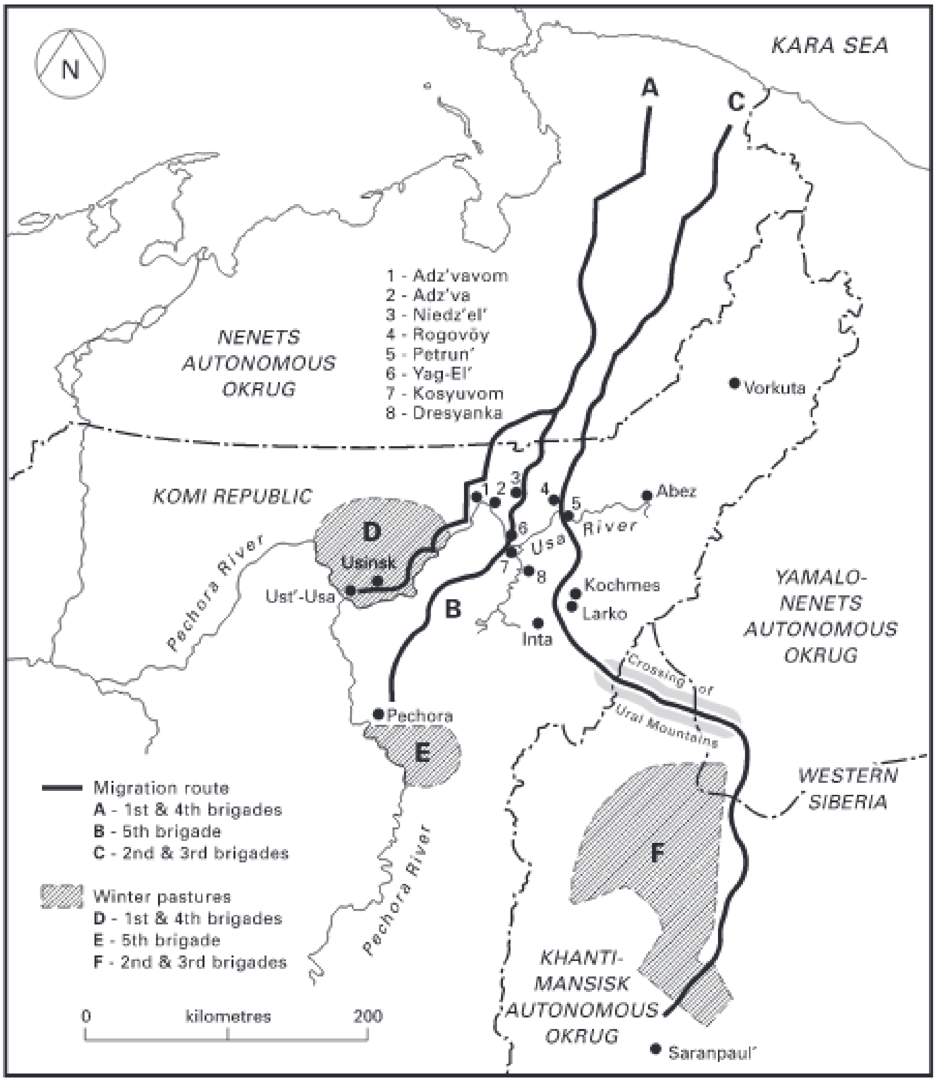

Figure 96. Map of Nenet and Komi herding routes. Image copied from Dwyer and Istomin 2009, 286 fig. 2.

The material sourcing patterns observed in record of the Swabian Jura reflects this kind of restricted territorial configuration. The movement of longer distance materials follows a heavy east/west directional bias (Burket and Floss 2006). In fact, this pattern is present throughout the Palaeolithic sequences of the region as indicated by the presence of materials derived from source locations in Bavaria within Middle Palaeolithic assemblages (Conard et al. 2012, 237). Towards the end of the Aurignacian, areas suitable to human occupation become increasingly restricted to valley floors. As the ecological context of the region shifted toward a cold and open environment, non-boreal reindeer and horse became the dominant prey species. This would have resulted in a decrease in population density and greater east-west movement by Gravettian and Magdalenian peoples mapped onto mobile prey moving down the Danube corridor and into the Ach and Lone Valleys (Weniger 1989). The resulting sourcing pattern became much less local and included greater numbers of long distance materials.

The Swabian Upper Palaeolithic sourcing pattern does not necessarily equate to a larger social extension or necessarily an unreasonably small population density. Rather, as distribution of resources changed from MIS3 to MIS2 so did the shape of the inhabitable landscape, exaggerating an already established east-west bias. For the Upper Palaeolithic more generally, it is clear from Discamps' (2014) faunal synthesis as well as the dataset used in this thesis, that reindeer become the predominant prey available to band communities. Mapping onto this species did not just simply foster a mode 4 fission-fusion system, but would have created a uniquely different inhabitable geography.

Demographic model

As with the long distance sourcing model, the demographic model matches many empirical observations (Figure **97**). One of the most important predictions of the model is an extirpation event occurring within a long period of demographic instability during the timeframe of the Middle to Upper Palaeolithic transition.

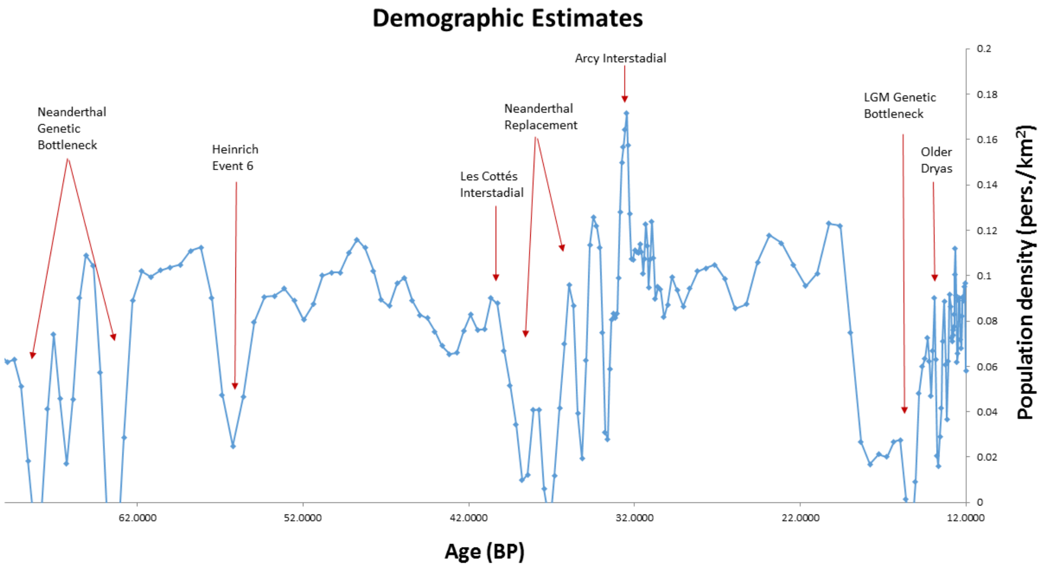

Figure 97. Predictive demographic model with highlighted observations.

The pattern predicted during the period of the Middle to Upper Palaeolithic transition is a reflection of the climatic instability of this period as recorded in the Grande Pile sequence. The period is capped by the Les Cottés and Arcy interstadials. The period between the Hengelo/Les Cottés and Arcy is considered to be one of the coldest stadial periods during MIS3 (Blades 2001, 50). Likewise, the timing of the extirpation event falls within the period observed for the replacement of the Chatelperronian and late Mousterian by the Aurignacian technocomplex (Higham et al. 2014). Other significant processes are predicted within the model.

For example, the model predicts two extirpation events prior to MIS3. This is mirrored in analysis of Neanderthal mtDNA diversity from Western European specimens, which suggests a major population bottleneck during this time-span (Dalén et al. 2012). Beyond the transitional period, another extirpation event is predicted for the LGM. Genetic evidence indicates a bottleneck during this period as well (Brewster et al. 2014; Pereira et al. 2005; Gamble et al .2005). Heinrich event 6 and the Les Cottés and Arcy interstadials are predicted to have had a significant impact on demography.

Heinrich event 6 coincides with the formation of the archaeological sequence recorded at Champ Grand. The demographic model predicts a significant drop in demography during this Heinrich event. The long distance sourcing pattern observed within the Champ Grand assemblage conforms to the assumption that longer sourcing distances during the Palaeolithic resulted from decreases in environmental carrying capacity. As such, the territorial area of *regional groups* would have increased during Heinrich event 6 as a response to lower resource abundance. The increase in territorial areas would have resulted in a recording of longer sourcing distances at archaeological sites as a product of band members moving within and between band territories. The demographic model suggests that the Les Cottés and Arcy interstadial would have been a time of demographic growth.

The Cottés is predicted to have had a less pronounced effect than did the Arcy interstadial. This event appears to have resulted in a small demographic rebound following Heinrich event 5. Following the extirpation event during the Middle to Upper Palaeolithic transition, the Arcy interstadial is predicted to have allowed significant demographic growth during the Aurignacian. These predictions mirror an analysis by Mellars and French that argued for a tenfold increase in demography from the late Mousterian to the Aurignacian based on site counts and site surface areas. However, the demographic model indicates that this demographic change-over was not a linear process. Rather, the demographic model indicates that demography was instable during the earliest periods of the Aurignacian and then significantly increased as a result of climatic amelioration during the Arcy interstadial. This was followed by a drop in demography toward a level similar to that predicted for the late Mousterian.

Applicability of the band model

The examination of the three test propositions led to each one being systematically rejected. As such, this thesis failed to demonstrate a difference in the fission-fusion patterns of Neanderthals and AMHs. This means that the central hypothesis, Neanderthal and AMH fission-fusion behaviour were not comparable, must also be rejected. To this end, Neanderthal and AMH community sizes have been estimated to be the same, Neanderthal and AMH territorial areas haven been shown to fall within the known range of those of modern hunter-gatherers, and Neanderthals and AMH were both shown to be equally capable of adjusting their territoriality and social organization to adapt to specific environmental conditions. These results highly suggest that Neanderthals and AMH shared a common form of sociality best described in the band model (Layton and O'Hara 2010).

Ultimately, the results of this thesis have demonstrated that the band model is highly applicable to understanding sociality during the late Pleistocene. It has proven capable of generating new interpretations within a unified theoretical framework based on empirical observations of hunter-gatherer social organization. This has allowed an exploration of sociality during the late Pleistocene without invoking an archaic/modern dichotomy. To this end, the band model has avoided the pitfall of behavioural modernity models that set the Upper Palaeolithic record as the standard by which everything that came before must be measured (McBrearty and Brooks 2000; Henshilwood and Marean 2003; McBrearty 2007). Specifically, a trait-list framework relies on synthetic descriptions of the archaeological record before and after the Middle/Upper Palaeolithic transition, which only stands to reinforce the archaic/modern dichotomy.

Barton et al. (2011) argue that a trait-list reduction lacks a firm, theoretical grounding. The *posteriori* standpoint of such models relies on an inferential assumption that the Upper Palaeolithic best reflects behavioural modernity and therefore any test proposition derived from the model becomes inherently circular in reasoning. The band model, by contrast, is grounded in fission-fusion studies, providing a theoretical basis removed from archaeological observations. Utilizing the band model to construct test propositions has therefore allowed an independent measure of the *modernness* of the sociality behaviours of Neanderthals and AMHs during the late Pleistocene.

Similarities and dissimilarities between the Middle and Upper Palaeolithic records can therefore be interpreted within a framework based within observations of extant hunter-gatherer social behaviour. For example, the similarity in the sourcing patterns recorded within the Aurignacian assemblage at Geissenklösterle compared to that of the Quina assemblages from Les Pradelles is not a result of an *archaic* social behaviour on the part first AMH inhabitants of Swabia. Alternatively, the similarity in the sourcing pattern recorded with the *Eastern European Charentian* assemblages of Raj cave to the Gravettian and Magdalenian pattern recorded at Hohle Fels does not mean that the occupants of Raj cave were any more modern than other Middle Palaeolithic communities. Instead, viewing these patterns within a band model framework has shown that they were products of the same sociobehavioural repertoire.

Conclusion

This chapter provided a general discussion of the steps taken within this thesis to test the applicability of the band model to Palaeolithic research. The examination of the three test propositions put forward to hold up the hypothesis that the sociality of Neanderthal and AMH were not comparable have been rejected. The examination of group size estimates for Neanderthals and AMHs was shown to be the same. This suggested that a modern community size predates the divergence of the Neanderthal and AMH lineages. The territorial areas of Neanderthals and AMHs were also shown to fall within the range of those of modern hunter-gathers. This suggested that differences in community territorial areas between the Middle and Upper Palaeolithic should have been the result of specific environmental circumstances, i.e. resource patterning and resource abundance. The examination of the relationship between site-level environmental information and sourcing patterns suggests that this is the case with a high level of confidence. Given these results, the primary hypothesis was rejected.

These tests have demonstrated the applicability of the band model to understanding sociality during the late Pleistocene. They have shown that removing the examination of the Middle and Upper Palaeolithic records from synthetic description of archaeological observation can generate new and robust interpretations. The following chapter concludes the thesis and provides some thoughts on future avenues of research.

CHAPTER 13

Conclusion

Introduction

Since William King's first description of the species *Homo neanderthalensis*, assessments of Neanderthal social behaviour have been overshadowed by the assumption that the "thoughts and feelings" possessed by this species were simian and brutish (King 1864). Recent genetic, palaeoanthropological, and archaeological findings have significantly undermined the assumption of specific biological and behavioural differences between Neanderthals and AMHs (Green et al. 2010; Reich et al. 2010; Hammer et al 2011; Mendez et al. 2013; Trinkaus 2011; Zilhão et al. 2010; Henry et al. 2011; Pike et al. 2012; Peresani et al. 2013; Rodriguez-Vidal et al. 2014). Despite these findings, trait-list arguments still continue to dominate research paradigms concerning the sociobehavioural capacities of Neanderthals and AMHs (Barton et al. 2011). Such analytical frameworks inherently invoke an archaic/modern dichotomy, resulting from theoretically weak and circular assumptions.

I have shown in this thesis that the band model provides an alternative and robust theoretical framework to study the sociality of Neanderthals and AMHs. The fission-fusion studies framework of the band model allowed the formulation of testable propositions that were not biased by inferences about the *modernness* of the archaeological dataset being examined. The testing of these propositions generated not just results with high levels of statistical confidence, but new interpretations. In this way, I have shown that the band model is highly applicable to the investigation of the archaeological record.

The following section concludes the thesis, providing a general summary of the test results presented in the previous chapters. This is followed by a brief discussion outlining further thoughts and research avenues.

Primary results

Using a band model framework, I put forth the hypothesis that Neanderthal and AMHs fission-fusion behaviours were not comparable. To test this hypothesis, three propositions were formulated: group size estimates for Neanderthals and AMHs are not comparable, Neanderthal territorial patterns should not suggest population densities that fall within the range of modern hunter-gatherer demography, and, Neanderthal and AMH territorial parameters did not respond similarly to environmental or ecological pressures.

Proposition 1:

To examine this proposition, I used the *social brain hypothesis* to examine whether a large brain (an average brain mass comparable to extant humans) was an ancestral or derived (i.e. parallel) trait of Neanderthals and AMHs. This was done by comparing a sample population of cranial volume measurements of *H. heidelbergensis* with a sample population of modern humans. Using a two-tailed t-test demonstrated no statistical difference ($p = 0.42$) between the two populations. Further analyses in this regard involved an examination of encephalization rates of Neanderthals and AMHs and potential for specialized selection on the brain structure of Neanderthals. These analyses failed to demonstrate significant differences between Neanderthals and AMHs. The implication of this is that groups size estimates for Neanderthals and AMH should be the same, leading to a rejection of proposition 1.

Proposition 2:

I used synthesized information of lithic raw material, site-to-source distances recorded from the Middle and Upper Palaeolithic records to test this proposition. Using Whallon's (2006) heuristic model, I suggest that territorial areas of Neanderthals and AMHs would have resulted in population densities that fit well within the known range of those of modern hunter-gatherers. The findings resulted in the rejection of the proposition.

Proposition 3:

To examine this proposition, I analysed the relationship between the site-level pattern of local material usage and faunal patterns within a dataset spanning the Quina Mousterian to the Magdalenian. This analysis demonstrated with a very high level of confidence ($p < 0.00$) the relationship between lithic raw material sourcing and environmental context across the entire dataset. Further examination showed no statistical difference ($p = 0.95$) in anticipated versus observed sourcing patterns between Neanderthals and AMHs. These results highly suggest that Neanderthals and

AMHs were capable of adapting their fission-fusion organization in kind to environmental and ecological pressures. As such, the proposition was rejected.
Given the strong correlation, the formula of the regression line was applied to Discamps' (2014) faunal synthesis from MIS 4 to MIS2 to model anticipated local material usage during these periods. The results of this model fit very well with archaeological observations, indicating a predominantly local material sourcing pattern for the Middle Palaeolithic and a reduction in local material usage during much of the Upper Palaeolithic.

The strong correlation between local material sourcing and faunal patterns was extrapolated to a macro-level environmental proxy (temperature estimates derived from the Grande Pile sequence) to model long distance material sourcing from MIS4 to the end of MIS2.

Long distance sourcing and demographic models:

The long distance lithic sourcing model fitted well with the known archaeological record. The model indicated that sourcing beyond 100km should be more highly anticipated during the Upper Palaeolithic than during the Middle Palaeolithic. The predictions of transfer distances beyond 100km for the Middle Palaeolithic fell within the general time range of known long distance material sourcing recorded at the site of Champ Grand. Combined with the local material sourcing model, this indicates that both local and long distance sourcing patterns observed within the Middle and Upper Palaeolithic were the result of the same fission-fusion adaptation to environmental conditions similar to that described for modern hunter-gatherers by the band model. The structure of the long distance sourcing model allowed the creation of a complementary demographic model.

As with the long distance lithic sourcing model, the predictions of the demographic model fit well with genetic and archaeological observations. The most significant finding of the demographic model was the prediction of an extirpation of the human population within a longer period of demographic instability coinciding with the timeframe of the Middle to Upper Palaeolithic transition. This prediction implies that demographic collapse and extirpation, at least of the population of Western Europe, would have occurred during this period regardless of demic association.

The results of examining the three test propositions combined with the predictions of both the long distance and demographic models strongly refutes the primary hypothesis that Neanderthal and AMH fission-fusion behaviours were not comparable. Rather, combined results suggest that Neanderthals and AMHs shared a common sociality reflected in the social organization of modern hunter-gatherers as described by the band model.

Synthesis:

1. The examination of the first proposition strongly suggests that a modern brain volume was an ancestral (rather than convergent) trait shared by Neanderthals and AMHs; according to the *social brain hypothesis*, Neanderthal and AMH group sizes therefore should have been the same.

2. The analysis of the second proposition indicates that the territorial areas of Neanderthal and AMH communities would have fallen within the range of those of extant hunter-gatherers, and by extension, Neanderthal and AMH population densities should have fallen within the range of those of modern hunter-gatherers.

3. The testing of the third proposition highly suggests that Neanderthals and AMHs were equally capable of adjusting their territorial parameters to local environmental and ecological conditions.

4. The modelling of local and long distance lithic sourcing patterns indicates that the observed lithic sourcing patterns from the Middle and Upper Palaeolithic records should be anticipated if Neanderthals and AMHs shared a similar band sociality.

5. The demographic model suggests that band-based communities regardless of demic association should have suffered a major demographic collapse during the timeframe of the Middle to Upper Palaeolithic transition.

6. These results reject the primary hypothesis that the fission-fusion behaviour of Neanderthals and AMHs was not comparable, suggesting that the most

parsimonious assumption is that Neanderthals and AMHs shared a similar social organization as described by the band model.

Further thoughts and research avenues

The first and foremost objective of future research should be an expansion of the dataset used in further applications of the fission-fusion heuristic model and statistical analysis of local lithic sourcing patterns. This should be done in terms of both the total number of assemblages and regions analysed. Future research avenues could also expand the chronological range examined. The results of this thesis indicate a likelihood that a band sociality extended back to the Middle Pleistocene. Likewise, a similar social system should have also underwritten the pattern of lithic sourcing during the Mesolithic and other prehistoric periods pertaining to hunter-gatherer archaeology.

This will have to involve an adaptation of the methods employed in this thesis to examine pertinent environmental information that would have had the greatest impact on scramble and contest competitions among communities. The increased availability of floral resources within tropical and subtropical environments (Marean 1997) is of particular concern. Dietary regimes directed more heavily toward floral resources would likely act to mediate the selective pressure caused by faunal patterning, i.e. daily movement and population densities, on the fission-fusion behaviour of hunter-gatherer communities. This may help, for example, to explain the continued use of river cobbles as a preferred raw material source throughout the late Pleistocene in southern China (Bar-Yosef and Wang 2012). There are of course other research avenues and implications that warrant further consideration.

Technological implication:

The effect of lithic sourcing patterns as a product of fission-fusion adaptation to specific environmental conditions may extend to some aspects of technological systems. For example, there is a potential correlation between lithic reduction and local sourcing patterns recorded within the Les Cottés sequence.

As local material decreases, the amount of cores compared to debitage decreases. This suggests an extension of reduction systems within the greater landscape. This makes sense as decreases in local material should correlate with increases in peripatetic behaviour as a result of adaptation to patterning and density of caloric resources in the environment. This relationship may have a bearing on the analysis of larger technological systems such as the use of bifacial and unifacial tools as portable cores (Kelly 1988; Hiscock et al. 2009; Féblot-Augustins 2008).

The sourcing of non-lithic materials:

Lithic materials were not the only items that were carried and exchanged by Palaeolithic peoples (Gamble 1999, 127). Both Féblot-Augustins (1999) and Whallon (2006) highlight the importance of marine shell sourcing during the late Upper Palaeolithic. In this case, the sourcing of some of these items beyond the maximum sourcing distances recorded for lithic materials may be difficult to fit within the analytical framework that has been established in this thesis. Likewise, the use of these different raw material categories and their occasional very large site-to-source distances may imply a new or different social mechanism was in play during the Upper Palaeolithic (Kuhn and Stiner 2001, 122).

However, the Middle Palaeolithic may not be so different. For example, I have personally examined a large bivalve from George MacCurdy's collections from the Mousterian site of Abri des Merveilles (Castel-Merle) housed at the Peabody Museum at Harvard. Further analysis is required to make sure that the mollusc shell is not that of a freshwater mussel. However, if it proves to be marine in origin, this would suggest a sourcing distance of at least 200km. Furthermore, as non-consumables in a strictly economic sense, potential items of ornamentation such as many late Upper Palaeolithic shells take on different life histories than those of tool stone. This means that their sourcing and subsequent movement around the landscape are governed by different mechanisms than those of lithic materials in most cases.

An example of this might been seen from the recent discovery of a fossil shell bead recovered from the Mousterian horizon at Fumane. The potential source location of this artefacts lies over 100km from the site (Peresani et al. 2013, 9). This stands in sharp contrast with the predominantly local lithic sourcing pattern of the Middle

Palaeolithic assemblages from Fumane (Spinapolice 2012, 686). Nevertheless, the fact that other materials were not as subject to the cycle of consumption as lithic materials means that a new methodological framework will have to be developed to contextualize these sourcing patterns within a band model framework.

Implications to the study of Palaeolithic demography:

The results of this thesis problematize the use of site counts and site surface areas as proxies for Palaeolithic demography. Reduction in caloric resource densities lowers the carrying capacity of any given environment. This results in a decrease in the population densities and subsequent increase in territorial areas of band-based communities. Under such conditions, higher rates of annual moves between sites should be anticipated (Binford 2001, 311). Depending on the patterning of caloric resources, the low resource density environments will either foster a mode 3 or mode 4 fission-fusion adaptation.

The low resource density and low resource patterning conditions of MIS4 glacial would have fostered a mode 3 fission-fusion adaption as indicated in the heuristic analysis of Les Pradelles. This mode should have resulted in a mobile settlement system. However, resource exhaustion rather than patterning would have dictated the timing and frequency of movement between sites (camps). As such, band sizes would be relatively small in order to mediate scramble competition. Therefore, a mode 3 adaptation would leave a potential archaeological pattern of many, small surface area sites. Such an archaeological signature might be more easily interpreted as one reflecting a mobile, low population density, system (Delagnes and Rendu 2011).

By contrast, the low resource density and high resource patterning of the last glacial would have fostered a mode 4 fission-fusion adaptation. Like mode 3, a mobile settlement system should have resulted from this fission-fusion adaption. However, as movement between sites (camps) would be dictated more by resource patterning rather than exhaustion, the mode 4 sites may have resulted in a greater peripatetic system. This would lead to a greater number of moves between sites (camps). Likewise, the patterning of resources would have resulted in a higher seasonal variability in band size. Higher seasonal variability in band composition, as a result of resource patterning (clustering), would allow for potential community aggregations. This would have resulted in a greater diversity in the spatial area of camps and the potential for larger accumulations of food waste (butchered bone) and other anthropogenic products. As such, this system has the potential to result in a larger number of archaeological sites with larger site surface areas compared to a mode 3 system.

Despite the likelihood that the true population densities of mode 3 and mode 4 fission-fusion systems would be comparable, their archaeological signatures may imply otherwise under certain analytical frameworks. As such, this questions the assumption that site counts (Bicho et al. 2000; Straus et al. 2000) can be used as a reliable measure of the demography of past hunter-gatherer populations. Likewise, the interpretation of site surface areas (Mellars and French 2011; Hayden 2012) is problematic as well. This is because the size of any given camp occupation would have been dependent on the clustering of local caloric resources rather than a reflection of demographic size (Birdsell 2009, 235).

Conclusion

In this thesis, I have shown the salience of the band model to archaeological investigation. The band model has demonstrated the ability to create new and robust interpretations. Most important of these being that Neanderthals and AMHs lived within a similar social fabric. The daily rhythms of their lives mirrored one another, being governed by the same environmental and ecological conditions that shape the social environments of hunter-gatherers to this day.

Appendix

Mid-summer temperature estimates (Grande Pile), population density estimates, territorial area estimates, and maximum material transfer distance (MTD) estimates:

^{14}C	July (est.)	Converted (-C° from present)	Pop. Dens. (pers./km $^{2)}$	Territorial Area (km^2)	Max MTD (km)
8.5000	8.3066	-8.3066	-0.067524	-7404.7768	Null
8.6500	8.2484	-8.2484	-0.0663425	-7536.6447	Null
8.8000	7.7469	-7.7469	-0.0561621	-8902.8058	Null
9.0000	5.4570	-5.457	-0.0096771	-51668.372	Null
12.0000	2.1128	-2.1128	0.05821016	8589.56581	104.57808
12.0500	0.2218	-0.2218	0.09659746	5176.11954	81.1815255
12.1000	0.2992	-0.2992	0.09502624	5261.70456	81.8499256
12.1500	0.6051	-0.6051	0.08881647	5629.58649	84.6629325
12.2000	0.5214	-0.5214	0.09051558	5523.91091	83.8645444
12.2500	0.9263	-0.9263	0.08229611	6075.62131	87.9529494
12.3000	1.6378	-1.6378	0.06785266	7368.90787	96.8627116
12.3500	1.4346	-1.4346	0.07197762	6946.60368	94.0462147
12.4000	0.5337	-0.5337	0.09026589	5539.19094	83.9804558
12.4500	0.5998	-0.5998	0.08892406	5622.77521	84.6116998
12.5039	1.7472	-1.7472	0.06563184	7618.25358	98.487876
12.5500	1.9278	-1.9278	0.06196566	8068.98531	101.359514
12.6125	0.4847	-0.4847	0.09126059	5478.81621	83.5215269
12.6468	-0.5309	0.5309	0.11187727	4469.18306	75.4343463
12.6736	0.0377	-0.0377	0.10033469	4983.32132	79.6552683
12.6969	0.9057	-0.9057	0.08271429	6044.9047	87.7303351
12.7204	1.1697	-1.1697	0.07735509	6463.69877	90.7184484
12.7473	1.2453	-1.2453	0.07582041	6594.53042	91.6319644
12.7800	1.3575	-1.3575	0.07354275	6798.7667	93.0400915
12.8202	1.4875	-1.4875	0.07090375	7051.8132	94.755725
12.8689	1.4124	-1.4124	0.07242828	6903.38083	93.7531731
12.9265	0.7197	-0.7197	0.08649009	5781.00913	85.7939942
12.9924	0.4558	-0.4558	0.09184726	5443.82053	83.2543547
13.0657	1.9183	-1.9183	0.06215851	8043.95086	101.202156
13.1451	3.1712	-3.1712	0.03672464	13614.8373	131.662255
13.2290	1.9927	-1.9927	0.06064819	8244.26912	102.454524
13.3157	0.6086	-0.6086	0.08874542	5634.09357	84.6968165

Table continued

13.4037	1.4860	-1.486	0.0709342	7048.78606	94.7353849
13.4917	2.9339	-2.9339	0.04154183	12036.061	123.793331
13.5787	3.5471	-3.5471	0.02909387	17185.7508	147.924229
13.6644	4.1968	-4.1968	0.01590496	31436.7342	200.066222
13.7490	3.9769	-3.9769	0.02036893	24547.1903	176.789291
13.8336	1.8725	-1.8725	0.06308825	7925.40608	100.453673
13.9198	0.5393	-0.5393	0.09015221	5546.17574	84.0333879
14.0099	1.6977	-1.6977	0.06663669	7503.37389	97.7424798
14.1070	2.6691	-2.6691	0.04691727	10657.0566	116.48599
14.2145	1.9082	-1.9082	0.06236354	8017.5051	101.03566
14.3366	1.4130	-1.413	0.0724161	6904.54195	93.7610572
14.4774	1.8539	-1.8539	0.06346583	7878.25512	100.154411
14.6416	2.0250	-2.025	0.0599925	8334.37513	103.012892
14.8336	2.6027	-2.6027	0.04826519	10359.433	114.847898
15.0578	4.5283	-4.5283	0.00917551	54492.8838	263.40557
15.3181	5.8409	-5.8409	-0.0174703	-28620.05	Null
15.6180	4.9195	-4.9195	0.00123415	405137.139	718.217673
15.9605	3.6228	-3.6228	0.02755716	18144.1048	151.992736
16.3475	3.6652	-3.6652	0.02669644	18729.089	154.423498
16.7802	3.9892	-3.9892	0.02011924	24851.8334	177.882931
17.2588	3.9353	-3.9353	0.02121341	23569.9965	173.234672
17.7824	4.1512	-4.1512	0.01683064	29707.7235	194.486628
18.3489	3.6702	-3.6702	0.02659494	18800.5688	154.717897
18.9552	1.3012	-1.3012	0.07468564	6694.72739	92.3254659
19.5972	-1.0291	1.0291	0.12199073	4098.67209	72.2398185
20.2699	-1.0797	1.0797	0.12301791	4064.44883	71.9375908
20.9670	0.0096	-0.0096	0.10090512	4955.14995	79.4297983
21.6820	0.2808	-0.2808	0.09539976	5241.10333	81.6895343
22.4075	-0.1741	0.1741	0.10463423	4778.55096	78.0015387
23.1358	-0.6528	0.6528	0.11435184	4372.47009	74.6136839
23.8592	-0.8191	0.8191	0.11772773	4247.08775	73.5361141
24.5698	-0.2416	0.2416	0.10600448	4716.78178	77.4957617
25.2603	0.6774	-0.6774	0.08734878	5724.1784	85.3712499
25.9237	0.7671	-0.7671	0.08552787	5846.04761	86.2752514
26.5538	0.1245	-0.1245	0.09857265	5072.40091	80.3640556
27.1454	-0.1790	0.179	0.1047337	4774.01257	77.9644893
27.6942	-0.1105	0.1105	0.10334315	4838.25004	78.4872683
28.1972	-0.0419	0.0419	0.10195057	4904.33746	79.0214933

Table continued

28.6526	0.3406	-0.3406	0.09418582	5308.65474	82.214288
29.0598	0.7250	-0.725	0.0863825	5788.20942	85.847406
29.4194	0.3706	-0.3706	0.09357682	5343.20358	82.4813803
29.7332	0.0826	-0.0826	0.09942322	5029.0063	80.0195582
30.0039	0.6880	-0.688	0.0871336	5738.3145	85.4765988
30.2353	0.9590	-0.959	0.0816323	6125.02649	88.3098292
30.4315	0.3546	-0.3546	0.09390162	5324.72177	82.3386077
30.5975	0.2976	-0.2976	0.09505872	5259.90672	81.835941
30.7381	0.5609	-0.5609	0.08971373	5573.28293	84.2384961
30.8584	-0.3259	0.3259	0.10771577	4641.84585	76.8777061
30.9633	-1.1218	1.1218	0.12387254	4036.4071	71.6890029
31.0574	-0.2966	0.2966	0.10712098	4667.61973	77.0908427
31.1447	0.3136	-0.3136	0.09473392	5277.94057	81.9761103
31.2287	-0.5856	0.5856	0.11298768	4425.26123	75.0627577
31.3121	-1.0650	1.065	0.1227195	4074.33212	72.025001
31.3970	-0.3120	0.312	0.1074336	4654.03747	76.978598
31.4849	0.0197	-0.0197	0.10070009	4965.23886	79.5106186
31.5763	-0.4508	0.4508	0.11025124	4535.09639	75.9885785
31.6716	-0.6239	0.6239	0.11376517	4395.01826	74.8058223
31.7703	-0.4392	0.4392	0.11001576	4544.8034	76.0698588
31.8717	-0.4531	0.4531	0.11029793	4533.17664	75.9724935
31.9750	-0.4975	0.4975	0.11119925	4496.4332	75.6639714
32.0790	-0.2922	0.2922	0.10703166	4671.51495	77.1230029
32.1827	-0.3172	0.3172	0.10753916	4649.46909	76.9408078
32.2853	-1.2801	1.2801	0.12708603	3934.34274	70.7768378
32.3861	-2.7815	2.7815	0.15756445	3173.30464	63.5639595
32.4847	-3.4774	3.4774	0.17169122	2912.20483	60.8928103
32.5811	-3.1198	3.1198	0.16443194	3040.77176	62.2224305
32.6755	-2.7367	2.7367	0.15665501	3191.72684	63.7481986
32.7687	-2.4081	2.4081	0.14998443	3333.67937	65.150383
32.8617	-1.3338	1.3338	0.12817614	3900.88202	70.4752244
32.9556	0.1027	-0.1027	0.09901519	5049.73025	80.1842643
33.0521	0.8756	-0.8756	0.08332532	6000.57702	87.4080771
33.1526	0.9755	-0.9755	0.08129735	6150.26197	88.4915632
33.2589	0.8719	-0.8719	0.08340043	5995.17293	87.3687086
33.3726	1.0109	-1.0109	0.08057873	6205.11145	88.8852815
33.4954	2.0893	-2.0893	0.05868721	8519.74391	104.152172
33.6285	3.6070	-3.607	0.0278779	17935.3538	151.115855

Table continued

33.7733	3.4614	-3.4614	0.03083358	16216.0865	143.69051
33.9306	1.2877	-1.2877	0.07495969	6670.2517	92.1565421
34.1012	-0.5592	0.5592	0.11245176	4446.35104	75.2414113
34.2854	-1.0326	1.0326	0.12206178	4096.28632	72.2187907
34.4833	-1.2114	1.2114	0.12569142	3977.99627	71.168407
34.6949	-0.6058	0.6058	0.11339774	4409.25895	74.9269168
34.9198	1.8888	-1.8888	0.06275736	7967.19301	100.718147
35.1574	4.0251	-4.0251	0.01939047	25785.8628	181.194868
35.4072	3.0497	-3.0497	0.03919109	12758.0019	127.451922
35.6685	0.7058	-0.7058	0.08677226	5762.21018	85.6543862
35.9405	0.2568	-0.2568	0.09588696	5214.47338	81.4817385
36.2226	1.5310	-1.531	0.0700207	7140.74552	95.3513481
36.5141	2.9289	-2.9289	0.04164333	12006.7247	123.642374
36.8145	4.4039	-4.4039	0.01170083	42732.0113	233.255411
37.1235	5.4813	-5.4813	-0.0101704	-49162.323	Null
37.4407	4.6928	-4.6928	0.00583616	85672.7711	330.275582
37.7659	2.9612	-2.9612	0.04098764	12198.7994	124.62742
38.0992	2.9732	-2.9732	0.04074404	12271.7335	124.999425
38.4405	4.3742	-4.3742	0.01230374	40638.0499	227.468618
38.7900	4.4987	-4.4987	0.00977639	51143.6225	255.18245
39.1477	3.2975	-3.2975	0.03416075	14636.681	136.513739
39.5138	2.4398	-2.4398	0.05157206	9695.17215	111.1048
39.8883	1.6860	-1.686	0.0668742	7476.72496	97.5687546
40.2712	0.6608	-0.6608	0.08768576	5702.18015	85.2070493
40.6623	0.5466	-0.5466	0.09000402	5555.30742	84.1025391
41.0616	1.2184	-1.2184	0.07636648	6547.37524	91.3037626
41.4686	1.2269	-1.2269	0.07619393	6562.20253	91.4070881
41.8830	0.9049	-0.9049	0.08273053	6043.71808	87.721724
42.3042	1.2580	-1.258	0.0755626	6617.03012	91.7881496
42.7318	1.7347	-1.7347	0.06588559	7588.91284	98.2980363
43.1651	1.7565	-1.7565	0.06544305	7640.2307	98.6298325
43.6037	1.5820	-1.582	0.0689854	7247.91043	96.0641774
44.0470	1.2677	-1.2677	0.07536569	6634.31861	91.9079801
44.4946	0.9750	-0.975	0.0813075	6149.4942	88.4860396
44.9463	0.9096	-0.9096	0.08263512	6050.69612	87.7723509
45.4020	0.6042	-0.6042	0.08883474	5628.4287	84.6542261
45.8617	0.1004	-0.1004	0.09906188	5047.3502	80.1653658
46.3258	0.2277	-0.2277	0.09647769	5182.54531	81.2319003

Table continued

46.7948	0.7151	-0.7151	0.08658347	5774.77433	85.7477174
47.2692	0.5818	-0.5818	0.08928946	5599.76508	84.4383938
47.7500	-0.0452	0.0452	0.10201756	4901.11702	78.9955442
48.2380	-0.5532	0.5532	0.11232996	4451.17224	75.2821926
48.7344	-0.7280	0.728	0.1158784	4314.868	74.1205813
49.2402	-0.4337	0.4337	0.10990411	4549.4204	76.1084881
49.7565	-0.0096	0.0096	0.10129488	4936.08364	79.276837
50.2842	-0.0080	0.008	0.1012624	4937.66689	79.28955
50.8241	0.0496	-0.0496	0.10009312	4995.34833	79.7513325
51.3769	0.6716	-0.6716	0.08746652	5716.473	85.3137708
51.9430	1.0128	-1.0128	0.08054016	6208.08302	88.9065622
52.5222	0.5986	-0.5986	0.08894842	5621.23532	84.6001129
53.1143	0.3400	-0.34	0.094198	5307.96832	82.2089726
53.7186	0.4921	-0.4921	0.09111037	5487.84952	83.5903524
54.3339	0.5157	-0.5157	0.09063129	5516.85847	83.8109919
54.9586	1.0582	-1.0582	0.07961854	6279.94434	89.4196482
55.5909	2.6960	-2.696	0.0463712	10782.5547	117.169855
56.2285	3.7569	-3.7569	0.02483493	20132.9337	160.106363
56.8687	2.6428	-2.6428	0.04745116	10537.1502	115.828823
57.5088	0.5419	-0.5419	0.09009943	5549.42467	84.0579975
58.1458	-0.5604	0.5604	0.11247612	4445.38805	75.233263
58.7765	-0.4853	0.4853	0.11095159	4506.46989	75.7483708
59.3981	-0.1841	0.1841	0.10483723	4769.29808	77.9259836
60.0075	-0.1292	0.1292	0.10372276	4820.54276	78.3435107
60.6022	-0.0560	0.056	0.1022368	4890.6069	78.9107984
61.1799	0.0842	-0.0842	0.09939074	5030.64974	80.032632
61.7387	-0.0440	0.044	0.1019932	4902.2876	79.0049773
62.2773	0.6030	-0.603	0.0888591	5626.88571	84.6426216
62.7949	3.5684	-3.5684	0.02866148	17445.0168	149.035852
63.2913	6.6501	-6.6501	-0.033897	-14750.555	Null
63.7669	5.8336	-5.8336	-0.0173221	-28864.894	Null
64.2227	2.1667	-2.1667	0.05711599	8754.11597	105.575028
64.6603	-0.1553	0.1553	0.10425259	4796.04392	78.1441794
65.0817	-0.3921	0.3921	0.10905963	4584.64787	76.4025848
65.4893	0.5462	-0.5462	0.09001214	5554.80627	84.0987456
65.8858	2.7386	-2.7386	0.04550642	10987.4607	118.277933
66.2741	4.1459	-4.1459	0.01693823	29519.0229	193.867964
66.6571	2.7271	-2.7271	0.04573987	10931.3822	117.97571

Table continued

67.0376	1.3317	-1.3317	0.07406649	6750.69117	92.7105547
67.4185	2.9585	-2.9585	0.04104245	12182.5086	124.544176
67.8023	5.3940	-5.394	-0.0083982	-59536.567	Null
68.1913	5.6428	-5.6428	-0.0134488	-37177.928	Null
68.5877	4.0728	-4.0728	0.01842216	27141.2256	185.895889
68.9933	2.4601	-2.4601	0.05115997	9773.26609	111.551373
69.4097	1.8770	-1.877	0.0629969	7936.89848	100.526479
69.8383	1.9323	-1.9323	0.06187431	8080.8982	101.434309
70.2808	1.7704	-1.7704	0.06516088	7673.31565	98.8431531
70.7384	2.3298	-2.3298	0.05380506	9292.80629	108.774852
0.0000	0.0000	0	0.1011	4945.59842	79.3532071
500.0000	-1.5000	1.5	0.13155	3800.83618	69.565616
410.0000	-2.0000	2	0.1417	3528.58151	67.0278264

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