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Evaluating Neanderthal Depopulation with Direct Neanderthal and Châtelperronian Radiocarbon Data

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EVALUATING NEANDERTHAL DEPOPULATION WITH DIRECT NEANDERTHAL AND CHÂTELPERRONIAN RADIOCARBON DATA

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Abstract

Evaluating Neanderthal Depopulations with Direct Neanderthal and Châtelperronian Radiocarbon Data

Thomas Lyman

Director: Tony Krus, Ph.D.

Homo sapiens neanderthalensis (Neanderthals) inhabited Eurasia approximately 350,000 years ago before experiencing population decline and disappearing from the archaeological record around 40,000 years ago (Yaworsky et al. 1). Radiocarbon dating has played a major role in establishing the timing of the last Neanderthals by both dating their skeletal remains and animal bones associated with their material culture. Widely discussed in the context of the last Neanderthals are the Châtelperronian stratigraphic layers as they possibly contain the last of Neanderthal material culture in regions of France and Spain. Whether the Châtelperronian should be attributed to Neanderthals or Anatomically Modern Humans (AMHs) is the subject of intense debate; however, many generally accept that this cultural layer should be attributed to the Neanderthals (Hublin et al. 18747-18748). What exactly caused the decline and disappearance of the Neanderthals is also widely debated. Radiocarbon dating methods have been used to both directly date the most recent Neanderthal remains as well as animal bones associated with the Châtelperronian. The radiocarbon dating of these samples has allowed for the approximate timing of both the end of the Châtelperronian and the last Neanderthals. If the Neanderthal-Châtelperronian association is correct, the end of the Châtelperronian should be closely temporally related to the last directly dated Neanderthals in France and Spain. The purpose of this study was to assess the Neanderthal-Châtelperronian association and apply relevant findings

to a greater discussion about radiocarbon dating and Neanderthal decline. Twenty-six radiocarbon measurements gathered from European Neanderthal remains as well as 58 measurements from animal bones located in Châtelperronian layers at the sites Grotte du Renne, La Ferrassie, Les Cottes, La Quina Aval, La Guelga, and Labeko Koba were compiled into OxCal. The Difference() command was used to establish the temporal relationship between the last European Neanderthals and the end of the Châtelperronian. For the sites that contained both dated Neanderthal remains and Châtelperronian associated bones, it was found that the Châtelperronian both predates and postdates the Neanderthal remains. It was also discovered that Châtelperronian and direct Neanderthal radiocarbon measurements support the end of the Neanderthals' occupation occurring approximately 40,000 years ago within Spain and France. These findings generally support the Neanderthal-Châtelperronian association as they demonstrate a close temporal relationship between the last Neanderthals and the Châtelperronian. An important implication of this study is that radiocarbon data alone is unable to definitively resolve the question of which hominins occupied the Châtelperronian or why the Neanderthals declined. For the time being, the debate on who is responsible for the Châtelperronian and what caused the Neanderthal decline will continue.

Chapter 1

Introduction

The Middle to Upper Paleolithic Transition (MUPT) (c. 35-45 Ky BP) was a time of dramatic change throughout Eurasia. The climate of the MUPT was marked by periods of extreme cold and aridity (Staubwasser et al. 9119-9120). Neanderthals, the hominin residents of Eurasia for over 350,000 thousand years, would be replaced by AMHs during this period. During the MUPT, genomic and archaeological evidence shows that Neanderthals were interacting with AMHs as well as other archaic hominins (e.g., Denisovans) (Rogers et al. 1, 3-7). A wealth of recent interdisciplinary studies in genomics (Chen et al. 683-685) paleoanthropology, archaeology, and microbiome analyses (Weyrich et al. 10) continue to broaden our horizons about this period. Nevertheless, by the end of the Upper Paleolithic, Neanderthal populations, as well as those of other archaic hominins, declined to the point where distinct subgroups were no longer being sustained. Though the causes of the Neanderthal population decline are heavily debated, including posed hypotheses about the co-occurrence of rapid climate change, admixture and possible competition with archaic hominins may have all played an important role (Timmerman 11-12). Notably, hiatuses in Neanderthal material culture at archaeological sites demonstrate a gap in occupation and coincide with the marked climate change of the MUPT. These hiatuses may suggest Neanderthal populations were struggling to adapt to the rapidly changing climate (Staubwasser et al. 9119-9120). Though Neanderthals were well adapted to cold environments during this period, the rapid onset of extreme aridity and cold would have put considerable stress on Neanderthal populations. The adaptive struggles that rapid climate change presented the Neanderthals and possible greater phenotypic plasticity witnessed in AMHs may explain the differential outcomes for these hominin groups during the MUPT. Though much research has been done to investigate the possible causes of Neanderthal decline, there are still many questions. Establishing the relationship between the demographic and climatic events of the MUPT is fundamentally important in establishing what caused Neanderthal population decline. For the true relationship of these events to be deciphered, their spatial-temporal relationships must be established as it is impossible to attribute causal or correlative relationships to events if their location and timing are unknown. Understanding the chronology of Neanderthal population decline at different sites in relationship to the timing of their interactions with AMHs and changing climate has been instrumental in developing current models of Neanderthal decline. Establishing the spatial-temporal relationship between events does not alone allow for establishing causality but is a necessary step for discovering correlations and serves as a useful starting point for building theoretical models.

The current body of chronological data surrounding Neanderthals and their decline has been due to the use of absolute dating methods such as radiocarbon and uranium-thorium dating. Before the widespread use of these absolute dating techniques, researchers had to rely on limited relative dating methods that simply do not allow for ascertaining the true age of Neanderthal archaeological material which prevented key insights from being gathered (Taylor and Bar-Yoseph 12). The widespread use of radiocarbon dating in particular has been useful in directly dating the remains of recent Neanderthals as well as animal bones associated with their material culture allowing researchers to approximate when the last Neanderthals existed and time their occupation/decline at different sites. This data can be contextualized with the established timing of other events of the MUPT to establish important temporal-spatial relationships that can possibly give insight into what caused Neanderthal population decline.

Figure 1. Map of Neanderthal territorial occupation. (Krause et al. 2)

Neanderthals occupied a large territory that stretched across Eurasia (Figure 1). The Neanderthals had their own established tool technology Mousterian (c. 160-40 Ky BP), and produced tools made from various materials (stone, wood, and bone), wooden spears (Hoffecker 1959-1960), and art (Hoffman et al. 359), and possibly body ornaments (Hublin et al. 18743). Many of these artifacts are found today in stratigraphic layers which are identified and classified by the types of material left in them. The Châtelperronian stratigraphic layers (c. 45-40 Ky BP) are likely the most recent and last Neanderthal associated stratigraphic layers present in France and Spain and are of importance in discussing the chronology of the decline of the Neanderthals (Djakovic et al. 7). The Châtelperronian is archaeologically significant at different sites such as Grotte du Renne, La Ferrassie, and Les Cottes because the Mousterian layers that precede it are definitively Neanderthal associated while the subsequent Aurignacian layers (an AMHs associated industry characterized by high-quality blade technology) are exclusively occupied by AMHs (Djakovic et al. 1). The relationship of the Châtelperronian to Neanderthal and AMHs associated layers implies that it occurs at the time of the transition between Neanderthal and AMHs occupation at these sites. Much debate exists about whether Neanderthals or AMHs occupied the Châtelperronian (see section – Neanderthals: The Châtelperronian)**.** If the Châtelperronian layers represent the last Neanderthal material culture in France and Spain, it would be reasonable to expect that the timing of the end of the Châtelperronian should be consistent with the timing of the last directly dated Neanderthal remains in close geographic proximity. The primary aim of this Honors Thesis is to evaluate the radiocarbon dating of Neanderthals in Europe as well animal bones associated with Châtelperronian layers found at the sites Grotte du Renne, La Ferrassie, Les Cottes, and La Quina Aval, La Guelga, Labeko Koba, and Cassenade to assess the temporal relationship between the Châtelperronian and the last directly dated Neanderthals in Europe. The goal of this analysis is to evaluate the validity of the Neanderthal-Châtelperronian association using radiocarbon measurements gathered from European Neanderthal remains and Châtelperronian associated animal bones. These measurements were compiled into OxCal and their temporal relationship will be evaluated with the Difference() command. This study also establishes the approximate timing of the last Neanderthals in accordance with both Châtelperronian and direct Neanderthal radiocarbon data. The results gathered from this study were applied to a greater discussion about the timing of the Neanderthal decline and their eventual disappearance and how this relates to the larger debate about the cause of these events. Finally, other implications of the results of this study, as well as the limitations of radiocarbon dating are discussed.

Radiocarbon dating is a direct dating method that analyzes the amount of radioactive Carbon-14 (^{14}C) present in organic remains (Taylor and Bar-Yoseph 21-23). Living organisms keep a consistent ratio of ^{14}C to ^{12}C isotopes during their lifetime, but after they die, they no longer take in ^{14}C. Since ^{14}C is a radioactive isotope, it undergoes beta decay where one of the neutrons converts into a proton, changing the ^{14}C into the stable isotope Nitrogen-14 (^{14}N). ^{14}C has a predictable half-life of ~5,700 years, meaning half of the ^{14}C present in a dead organism decays into ^{14}N approximately every 5,700 years. This predictable pattern of decay allows scientists to analyze the ratio of ^{14}C to ^{12}C in the tissues of remains to establish an approximate time of death. In the case of dating bones associated with the MUPT, bone collagen is used for isotope analysis as it is the best-preserved protein from ancient remains. The amount of ^{14}C in the atmosphere has not always been constant which complicates radiocarbon dating because this means at different times, an organism would have died with varying amounts of ^{14}C present in their tissue (Bard et al. 21005). As a result, scientists have developed calibration curves that produce accurate radiocarbon calibrations by considering the different amounts of ^{14}C in Earth's atmosphere over the past ~50,000 years. These calibration curves have been developed in part by taking radiocarbon measurements of wood that have been conclusively dated by dendrochronological methods.

Background

Utility of Radiocarbon Data for Understanding Neanderthals

Though radiocarbon dating is useful for allowing researchers to establish the approximate timing of Neanderthal decline and their disappearance from Eurasia, it alone does not allow for the establishment of cause. Many other disciplines are required to construct theoretical models built on archaeological data to determine possible causes. Studies into Neanderthal microbiome (Weyrich et al. 10) and genetics (Chen et al. 683-685) are particularly important as they highlight the frequency and nature of interactions that were occurring between Neanderthals, AMHs, and Denisovans (*Homo sapiens denisova)* (Slon et al. 113-116). These microbiome and genetic studies indicate that interactions and genetic introgression between these archaic hominins occurred across evolutionary history. These are important findings as genetic introgression and hominin admixture are frequent points of discussion when evaluating both Neanderthal evolution and their decline. Radiocarbon dating also faces several limitations that have prevented it from providing more useful data for understanding Neanderthals (see section – Usefulness of the Dataset and Limitations).

Identifying Characteristics and Human Evolution

Genetic evidence suggests that early ancestors of Neanderthals and Denisovans who diverged from African-dwelling archaic hominins expanded out of Africa and arrived in Eurasia 700 thousand years ago and mixed with a "Super-Archaic" hominin population that was already present (Rogers et al. 3-5). After arrival in Eurasia, the ancestral population of Neanderthals and Denisovans would split into the two hominin groups though evidence of continued admixture exists between the groups (Slon et al. 113-116). AMHs, who continued to radiate in Africa after their split from Neanderthals and Denisovans, began major expansions out of Africa approximately 50 thousand years ago. The expansion of AMHs into Eurasia resulted in a large degree of admixture between them and the archaic hominins (Neanderthals and Denisovans) already present, this is referred to as the Assimilation model (Figure 2).

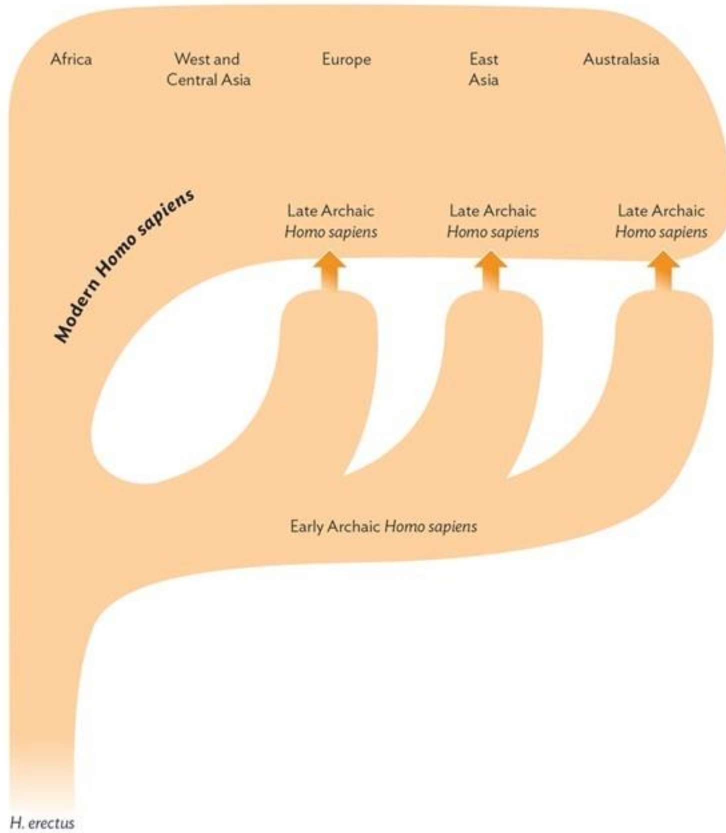

Figure 2. Assimilation model of human evolution showing that as humans migrated out of Africa, they interbred with other already present populations of archaic *Homo sapiens* (Larsen, slide 37).

Neanderthals would be replaced by AMHs in Eurasia shortly after this expansion during the MUPT. For a greater understanding of why there were differential outcomes for Neanderthals and AMHs during the MUPT, it is important that key characteristics and cognition of the Neanderthals be highlighted. After their evolutionary split, Eurasian Neanderthals and African AMHs would morphologically diverge to adapt to different ecological niches. The skeletal remains of Neanderthals highlight several anatomical differences between them and AMHs. Neanderthals were shorter and stockier than AMHs, standing on average just over five feet. One of their most characteristic features is the robust brow ridge they have that AMHs lack.

Interestingly they have a larger cranial capacity in comparison to AMHs (Havarti 383-384). The anatomical study of Neanderthal and reconstruction of their ear cavities has led to strong evidence that they possessed similar speech and auditory capabilities to AMHs (Conde-Valverde 612). Neanderthal hyoid bones also demonstrate speech-related adaptations similar to AMHs (Barney et al. 88). Genetic research has found that both Neanderthals and AMHs possess the same variant of the FOXP2 gene that is crucial for modern speech capabilities, further reinforcing the notion of similar speech capabilities between them (Krause et al. 1911). Study of Neanderthal arm and shoulder anatomy suggests that they did not regularly throw objects which would have been a vital part of long-range hunting (Rhodes and Churchill 7-9). They also possess injury patterns similar to rodeo workers, which is indicative of close-range contact with large animals (Berger and Trinkaus 850). These injury patterns and lack of evidence for regular throwing in tandem imply that Neanderthals primarily engaged in close-range hunting. Though evidence supports the idea that Neanderthals were primarily close-range hunters it is apparent they produced spears (Hoffecker 1959-1960). Experimental research that has been conducted with trained javelin throwers suggests that Neanderthals would have been able to throw these spears effectively (Milks et al. 1,6-7). Neanderthals have been estimated to have significantly higher caloric demands than AMHs. Dietary isotope analysis of Neanderthals has revealed a varied diet that likely included a variety of terrestrial herbivores as well as substantial plant-based contributions (Naito et al. 87-88). Analysis of tools used by Neanderthals, animal bones associated with their activity, and dental calculus supports the idea that Neanderthals exploited a variety of food resources outside of large terrestrial herbivores such as fish, birds, and starchy plants (Hardy and Moncel 6-8). Neanderthals possess a gut microbiome that shows strong evolutionary relatedness to AMHs, which hints at a shared core gut biome that predates the divergence of these hominin species (Rampelli et al. 7). The presence of strains of bacteria that improve nutritional gain from plant fibers found to be a part of the Neanderthal gut biome further reinforces the notion that plant-based nutrition was an important part of their diet (Rampelli et al. 7). Neanderthals may have varied in many anatomical ways from AMHs, but they possessed many of the same capabilities. They had dexterous hands that were adept at producing stone tools, which is also a key feature in AMHs. They stood upright like their AMH counterparts surveying the land with their larger eyes.

Cognition

Understanding the cognitive capabilities of Neanderthals has been a major focus of paleoanthropological research. Skeletal remains of Neanderthals have provided some clues into the cognitive capabilities of Neanderthals. Their large cranial capacities imply they had brains larger than AMHs which is an indicator of extensive cognitive resources. The aforementioned speech-related adaptations witnessed in Neanderthal skeletal remains are another indicator of advanced cognition. Modern genetic research has provided more insight into what Neanderthal brains were like and how similar they were to AMHs. There are many gaps that still need to be filled, but the archaeological record does provide a large degree of insight into their cognitive abilities.

The artifacts the Neanderthals left behind demonstrate that they were very intelligent. Just like their AMH counterparts, they produced stone tools that they used for a wide range of applications. The characteristic Neanderthal tool industry of the Middle Paleolithic is the Mousterian. Mousterian stone tools were made with advanced techniques such as Levallois, a technique that required a stone core to be prepared by chipping at it, reducing it for a final high-quality flake to be produced. These high-quality flakes would then be used as tools. Neanderthals used these tools for the butchery of animals, art, woodworking, and the processing of their hides (Reubens 351). Hunting was also another important application of certain Neanderthal stone tools that were made into points and some even demonstrated notches that suggest Neanderthals produced hafted tools (Lauzen 2306-2307). There is ample evidence that Neanderthals further retouched and modified their tools in accordance with their needs (Hoffecker 1960). It is clear that Neanderthals developed stone tools with a variety of advanced techniques that would have required advanced planning and a complex understanding of the physics of tool-making comparable to AMHs (Hoffecker 1960). Neanderthals would have had to be able to identify the correct stone for the task at hand and remember where these stones were found. After procuring the correct stone they would presumably have passed down this knowledge from one generation to the next.

The symbolic capabilities of Neanderthals are an often-discussed aspect of their cognition. The archaeological record for symbolic thought and expression is rather barebones for Neanderthals compared to AMHs in the Upper Paleolithic, but there exist several findings from the archaeological record that demonstrate that Neanderthals employed abstract symbolism. The use of uranium-thorium dating in Spanish caves where ancient red ochre cave art is present has pushed back the date of its creation well before the arrival of AMHs, leaving the Neanderthals as the most likely creators (Hoffman et al. 359). In Bruniquel cave in Southwestern France, a structure made of broken stalagmites has been found with an age of over 175 thousand years. The age of this structure and evidence of the use of fire point to Neanderthals being the likely creators (Jaubert et al. 112-114). Though it is impossible to determine the exact purpose of this structure it likely had some symbolic or ritual-related purpose. The presence of evidence of fire and symbolic expression at this site demonstrates a high level of Neanderthal sophistication far back in time before interactions with AMHs. Neanderthals have also been demonstrated to be the likely creators of shells that have been stained by pigment in Iberia (Zilhao et al. 1027-28). At the site of Grotte du Renne, cultural artifacts such as colorants and bone pendants have been found in the Châtelperronian layers (Welker et al. 11162).

It is evident from Neanderthal skeletal remains that they engaged in healthcare. Many Neanderthal skeletons show evidence of recovery from major injuries or illnesses that would have required long-term care (Spikins et al. 99). Analysis of Neanderthal dental calculus provided evidence that a Neanderthal individual used self-medicated with poplar which contains both analgesic and antibiotic properties to possibly treat a dental abscess (Weyrich 7). Microbiome research of this individual demonstrated they were suffering from microsporidia which causes diarrhea, demonstrating another possible reason for self-medication. Shanidar 1, a Neanderthal skeleton recovered from Shanidar cave belongs to an individual who lived for at least a decade with multiple disabilities including a damaged leg, withered arm, and probable partial hearing and vision loss. This individual would have likely required long-term care and provisions from their group while being unable to effectively hunt or gather (Spikins et al. 99). The lack of obvious economic benefit of long-term care of this individual is strong evidence of remarkable compassion among Neanderthals. Shanidar cave has also yielded evidence that the Neanderthals intentionally buried their dead. The validity of the evidence of intentional burials has been hotly debated, but recent excavations at Shanidar Cave that involve newly found remains provide strong evidence that Neanderthals engaged in intentional burials (Pomeroy et al. 23). The Shanidar 4 Neanderthal skeleton was found associated with sediment that contained clumps of pollen grains, which has been believed to be evidence that the individual was buried with flowers (Pomeroy et al. 12). This interpretation has had doubt cast on it as some research suggests that bees are responsible for the clumps of pollen (Hunt et al. 6-9). Regardless of the interpretation of the Shanidar 4 burial, there is strong evidence from Shanidar cave that Neanderthals took care when burying their dead. The combined evidence of long-term healthcare and mortuary practices highlights both the sophistication and compassion of the Neanderthals.

The study of Neanderthal genetics has also yielded some insight into their intellectual abilities. A study found that genetic polymorphism attributed to the Neanderthals in human DNA increased the functional connectivity of regions attributed to visual processing, but decreased it in regions attributed to social cognition, which is consistent with theories pertaining to Neanderthals having greater visual processing abilities at the cost of social abilities (Gregory et al. 38,41-43). As it stands the current body of evidence dispels outdated narratives of Neanderthals lacking in intellectual and cultural ability. It is clear that Neanderthals were very intelligent, creative, and compassionate hominins who successfully populated Eurasia for hundreds of thousands of years.

Genetics and Interactions with AMHs

One of the key events that set the scene for the decline of the Neanderthals was the interactions and admixture (interbreeding events with other archaic hominins) of AMHs into Eurasia. AMHs began their major excursions into Western Eurasia around 60 thousand years ago. During this period considerable gene flow occurred between AMHs and Neanderthals. Modern populations today also show evidence of extensive admixture with Denisovans, another member of the genus *Homo* that occupied much of northeastern Eurasia and interbred with AMH and Neanderthals. (Zhang 4-5). Radiocarbon dating demonstrates that in the regions of Northern Spain and France, there was around 1,400-2,900 year overlap of occupation between these two groups of hominins in northern Spain and France. It has also been suggested that the appearance of more complex cultural artifacts in the Châtelperronian layers is due to AMHs' cultural influence on the Neanderthals (Hublin et al. 18743).

It is estimated that 1-4% of the genome of modern people is composed of Neanderthal DNA (Reilly et al. 970). Though Neanderthal DNA has not been historically attributed to modern African populations, recent research has revealed the presence of Neanderthal DNA in their genomes (Chen et al. 683-685). The widespread presence of Neanderthal DNA across modern human populations is strong evidence of extensive admixture. This genetic admixture has many consequences on AMHs today. Neanderthal genetic material is shown to play a role in hair and skin pigmentation, with the Neanderthal haplotype having alleles associated with blue eyes, blond, and red hair (Reilly et al. 975) Genetic material from Neanderthals also has a demonstrated effect on the metabolism, with one Neanderthal derived haplotype being associated with an increased risk of diabetes. Research has also shown that there are many Neanderthal-derived genes associated with immunity and viral responses, which modulate the AMH immune system (Reilly et al. 976). There is evidence of positive selection for some of these immune genes. One of these genes that shows evidence of positive selection has been demonstrated to be a risk factor for severe SARS-CoV-2 infection, suggesting it may serve some other immune function (Zeberg and Paabo 610-611). Other research suggests that Neanderthal-derived genetic variation may protect against COVID-19 susceptibility (Zhou 665-666). There is still much ongoing research on Neanderthal genetics as it is a rapidly expanding field that is key to the modern understanding of human evolution. Overall, the wealth of Neanderthal genetic information in the modern-day gene pool has ramifications not only for AMHs phenotypic variation but also for modern theories pertaining to the decline of the Neanderthals.

Previous Research on the Neanderthal Decline

Scholarship focused on understanding the population decline of the Neanderthals is truly multidisciplinary and informed by many perspectives. Most of the literature on this topic includes discussion about AMHs' roles in this process. When AMHs began making their major excursions into Western Eurasia around 60 thousand years ago, it would only take 20 thousand years for Neanderthals to entirely disappear from the archaeological record. (Stringer and Crete 403). This period is marked with AMH-Neanderthal geneflow as well as occupational overlap (Djakovic et al. 8). Teeth have been found to possibly represent dual hominin ancestry found at the site of Les Cottes, but all additional evidence demonstrating Neanderthal-AMHs admixture is primarily genetic (Stringer and Crete 407). The small sample size of Neanderthal remains may explain why less hybrid remains have been identified.

One mechanism of Neanderthal decline could have been competition with AMHs. Ecocultural niche modeling has demonstrated that both hominin groups exploited similar niches (Gilpin et al. 2134). This means as AMHs made their excursions into Neanderthal-inhabited regions of Eurasia they would be exploiting the same resources which would likely lead to competition. This competition would have put further strain on Neanderthal populations who were already struggling with the rapid onset of aridity and extreme cold (Staubwasser et al. 9119-9120) that had a reduced carrying capacity of herbivores they relied on for survival (Vidal-Cordsasco et al. 13). Though the climate change near the end of the Marine Isotope Stage 3 (57k-29k BP) would have put strain on hominin populations that would have required adaptations, modeling of climatic and econiche data points to competition with humans being a more primary factor Neanderthal decline (Banks et al. 1, 3-5). A study that modeled competition between Neanderthals and AMHs found that if AMHs possessed greater reproductive rates, mobility, and adaptive plasticity they would have been able to outcompete a fragmented by climate change Neanderthal population (Timmerman 11-12). The competitive exclusion simulated by this model would have led to Neanderthal population decline. It has been suggested that the innovations of the AMHs Aurignacian industry and the domestication of dogs could have helped AMHs thrive in Eurasia (Timmerman 11-12). This study also found that climate change only played a minor role in the overall decline of the Neanderthals and that the impacts of climate change varied by region. Many of the models of AMHs' competition with Neanderthals are built on at least in part assumptions about the relative capabilities of the species which limits their usefulness since they are largely hypothetical. Recent research only continues to highlight the advanced capabilities of Neanderthals leaving many assumptions about their abilities unfounded. Until more definitive data pertaining to the topic of the relative competitive advantages of these hominins is produced, the modeling of their competition will continue to be largely assumption-based.

Another important model of Neanderthal decline focuses on the fact that Neanderthals had smaller dispersed populations. Instead of direct competition with AMHs, small population size, demographic factors, and inbreeding may have been what led to Neanderthal decline according to Vaesen et al. (10). AMH incursions would have further isolated the small Neanderthal populations, exasperating the demographic problems of having a small population. These populations would become increasingly vulnerable, and over time would see themselves diminish. One other important consideration when examining possible causes of Neanderthal decline is disease. AMHs could have brought a viral disease from Africa. AMHs would have evolved alongside this virus, meaning they would have had natural defenses against it. On the other hand, the geographically separated Neanderthals would not have the same defenses and would have been very negatively affected by it. The Human Herpes Virus 3 has been proposed as a probable culprit (Wolff and Greenwood 101-103). Though there exist multiple hypotheses of how exactly the Neanderthals declined, the most popular conceptions in one way or another posit blame on AMHs.

The Châtelperronian

The Châtelperronian stratigraphic layers are unique as they represent an Upper Paleolithic industry that has been generally attributed to the Neanderthals as it is their remains that are found within these contextual layers (Hublin et al. 18743). It is significant in the story of Neanderthals because bladelets and body ornaments, artifacts that have traditionally only been associated with AMHs, are found in these layers. The attribution of these artifacts to Neanderthals demonstrates their technological sophistication and their advanced artistic abilities. The layers above the Châtelperronian are undoubtedly AMHs associated, meaning the Châtelperronian possibly represents the last contributions to the archaeological record by Neanderthals in regions of France and Spain. Concerns that Neanderthal remains attributed to the Châtelperronian are from older Middle Paleolithic layers, and concerns that artifacts produced from Upper Paleolithic AMHs may have admixed in lower layers cast doubts on Neanderthal association (Hublin et al. 18743). Radiometric research at the Châtelperronian site of Grotte du Renne has found no evidence of co-occupation, further supporting Neanderthal association (Hublin et al. 18747-18748). Assuming Neanderthal association, the radiocarbon dates of the animal bones found in Châtelperronian layers can serve as a useful proxy for dating the end date of Neanderthal occupation.

Research Design

Though much research about the timing and chronology of the Neanderthal decline and their association with the Châtelperronian has been conducted, limited archaeological material and difficulties in resolving stratigraphy have prevented clear answers from being established. A better understanding of the decline of the Neanderthals and their relationship to the Châtelperronian can be gained from looking at site-based radiocarbon data trends and comparing them with a larger body of data. The information gathered from this can be contextualized within a larger discussion about the timing and causes of the decline of the Neanderthals. The research design for this Honors Thesis is built around two types of data sets. The first data set is composed of radiocarbon measurements that have been gathered directly from Neanderthal remains from primarily Western European sites. The second data set is of site-based radiocarbon measurements gathered from animal bones associated with the Châtelperronian layers. These data provide two different perspectives on the timing of the last Neanderthals. The data set available for directly dated Neanderthals is sparse as limited dateable material has been recovered. Though the opportunities to directly date Neanderthals are far and few between, they remain a very important aspect of understanding the decline of the Neanderthals as they represent the most direct way to approximate when the last Neanderthals walked the Earth. On the other hand, the Châtelperronian has many radiocarbon measurements associated with specific sites. Not all Châtelperronian sites have a robust amount of Châtelperronian material that has been dated, but the ones that do provide a relatively large sum of regional radiocarbon measurements that can provide insight into the timing of the last Neanderthals on a regional level if Neanderthal association is assumed.

The collected Châtelperronian and direct Neanderthal measurements that have been compiled will be used to evaluate the timing of the last Neanderthals as well as the Neanderthal-Châtelperronian association. This will be done on a site-by-site basis using Châtelperronian data. Once a site-by-site analysis has been completed the Châtelperronian data set will be evaluated as a whole and compared with the direct Neanderthal data set. The information gathered from the comparison of the data sets will then be able to be used in a larger discussion about radiocarbon dating and the decline of the Neanderthals.

Chapter 2

Methods

Two different types of chronological scales were investigated to understand how radiocarbon dating informs discussions about the decline of the Neanderthals. The first is a continental-wide assessment of radiocarbon measurements produced from directly sampled remains compiled by Bard et al. and Djakovik et al. The second is a regional scale assessment of the territory spanning modern-day France and the Iberian Peninsula through the compilation of radiocarbon measurements from samples of animal bones associated with the robustly dated Châtelperronian sites described by Djakovik et al. (Grotte du Renne, La Ferrassie, Les Cottes, La Quina Aval, La Guelga, and Labeko Koba). The Châtelperronian lithic assemblage was chosen as it likely represents the last material culture left behind by Neanderthals and provides a robust data set for understanding the chronology of the end of the Neanderthals at a regional scale. Additional dates not found in the Bard et al. and Djakovic et al. databases but in other primary sources were compiled to provide a wider range and more up-to-date collection of radiocarbon data. Newer data for Spy and Vindija cave used as revaluations from Deviese et al. provided updated radiocarbon data because Deviese et al.'s dataset corrects for contamination that skewed older radiocarbon measurements from these sites. Additional recent dates from Sala and Sublyak were also included in the site to employ recent data from Eastern sites. This data is included in the OxCal code in the supplemental appendix. For direct data access, email the author.

The Châtelperronian sites examined are all located in France and Spain and consist of stratigraphic layers with Châtelperronian material culture. The data from Djakovic et al is what is primarily analyzed but additional radiocarbon data from anthropogenically modified animal bones were compiled to generate a more comprehensive dataset that accurately represents the radiocarbon data associated with the sites of Grotte du Renne and La Ferrassie.

The direct and Châtelperronian uncalibrated radiocarbon dates and their 1 sigma error that had been compiled into Excel were inserted into OxCal to calibrate with the modern IntCal20 radiocarbon calibration curve. The IntCal20 calibration was published in 2020 by Reimer et al. and was updated with new dendrochronological data and accounts for the Laschamp geomagnetic excursion (42,200-41,500 BP) (Bard 2105-2107). Terrestrial radiocarbon calibrations from the Pleistocene published prior with these older calibration curves may be offset because they do not fully correct for the effects of the Laschamp geomagnetic excursion. Therefore, the calibrations produced for this thesis use the IntCal20 calibration curve and provide an updated assessment for the timing of both the Châtelperronian at the examined sites and the last Neanderthals.

All the other Châtelperronian sites yielded measurements from modified bones, with the exception of the Châtelperronian radiocarbon measurement from La Guelga that just came from unmodified bone (which was only used due to it being the Châtelperronian measurement from the site). The preference for modified bones over those that were unmodified is because their anthropogenic modification is a positive indicator of hominin activity in a particular stratigraphic layer. Conversely, unmodified bones cannot be securely attributed to hominin activity. Though less useful than modified bones, unmodified bones can still be used as a proxy for dating the geological layers in which they are found, especially when there is a lack of archaeological material. Radiocarbon measurements from charcoal were excluded from this study due to several issues, such as the old-wood effect (heartwood of trees may be deceased for centuries before burning, skewing apparent age of measurements), natural burnings, and bioturbation reduce the reliability of charcoal dating (Ashmore 124-125, 127-128). Overall, the compiled radiocarbon measurements from modified bones found in the Châtelperronian stratigraphic layers directly date hominin activity and serve as a proxy for the timing of Châtelperronian activity.

Radiocarbon measurements from Neanderthal skeletal remains were used for this analysis because they represent the most direct chronological information regarding the last Neanderthals. The direct dating of a Neanderthal skeleton provides an extraordinary opportunity to definitively establish when a particular Neanderthal died without the need for proxies. The compiled dates gathered from these measurements provide an additional dataset to assess when Neanderthals disappeared from the archaeological record.

Radiocarbon Dating and OxCal

A total of 26 radiocarbon measurements acquired directly from Neanderthal remains were included in the data set of this study, along with 58 measurements from animal bones associated with Châtelperronian from robustly dated sites. Once the data was inserted in OxCal 4.4 and calibrated with IntCal20 the Difference() command in OxCal was used to analyze the chronological relationship between the dated materials. The Difference() command allows for the calculation of the difference between two parameters (OxCal). This command uses probabilistic subtraction to calculate the temporal distance between two parameters in OxCal. Difference() was used to estimate the temporal relationship of the following parameters: 1) the time difference between the youngest and oldest Châtelperronian measurement at each site (excluding La Guelga), 2) the time difference between the youngest and oldest direct Neanderthal measurement, 3) the time difference between the youngest Châtelperronian measurement and the youngest directly dated Neanderthal measurement, and 4) the time difference between the youngest anthropogenically modified Châtelperronian measurement and youngest directly dated Neanderthal measurement. The sites of Grotte du Renne, La Ferrassie, and Les Cottes contained both Châtelperronian measurements and measurements from Neanderthal remains, so the Difference() command was used to compare the youngest Châtelperronian measurement and direct Neanderthal measurements at each of these sites. Overall, the Difference() command was used on these parameters to assess both site-based and overall trends in the data set.

Châtelperronian Site Selection: Overview

The Châtelperronian sites that were selected for this study fall within northern Spain and France; the regions where the Châtelperronian is predominantly found. This analysis uses the sites that Djakovic et al. used in their study, all contained Châtelperronian layers with associated animal bones which yielded radiocarbon measurements. Both the sites of Grotte du Renne and La Ferrassie also contained Neanderthal skeletal remains that have yielded radiocarbon measurements.

Grotte du Renne

Grotte du Renne is an archaeological site located at Arcy-sur-Cure in France. It is one of the richest Châtelperronian sites (Hublin et al. 18744). It contains Mousterian, Châtelperronian, and Protoaurignacian layers. This site has yielded a wealth of radiocarbon measurements from anthropogenically modified bones from its Châtelperronian layers. Only radiocarbon measurements from the modified bones at this site were used. This site has the largest collection of measurements used for this study (31 Châtelperronian measurements). These layers also contained hearths that were excavated. Neanderthal skeletal remains were also found at Grotte du Renne, and one has yielded the radiocarbon measurement MAMS-25149. Though the association between skeletal remains and Châtelperronian material culture in these layers is debated, analysis of the radiocarbon collected from the site demonstrated that the skeletal remains and the Châtelperronian date ranges overlap, suggesting Châtelperronian association (Hublin et al. 18745).

La Ferrassie

La Ferrassie is one of the most important Paleolithic archaeological sites. It is located in France. The site has yielded largely intact Neanderthal skeletons that have played an important role in understanding their morphology (Talamo et al. 961). It contains Mousterian, Châtelperronian, and Aurignacian layers. This site yielded radiocarbon measurements from both modified and unmodified animal bones associated with the Châtelperronian layers that were used for this analysis. The La Ferrassie 8 Neanderthal skeleton found at this site yielded one of the youngest direct Neanderthal radiocarbon dates and the dating of this skeleton is consistent with the Châtelperronian layers at the site (Balzeau et al.).

Les Cottes

Les Cottes is a cave that is located in Central France. Mousterian, Châtelperronian, Protoaurignacian, and early Aurignacian layers are present at this site. It has provided a wealth of Châtelperronian lithic artifacts (Talamo et al. 176). Several animal bones associated with the Châtelperronian layers at this site have been excavated. Radiocarbon measurements from both modified and unmodified animal bones have been collected from the Châtelperronian layers at this site, both of which are used for this analysis. Neanderthal remains have also been discovered at this site and have been radiocarbon-dated.

La Quina Aval, La Guelga, Labeko Koba, and Cassenade

The site of La Quina Aval is located in France while the sites of La Guelga, Labeko Koba, and Cassenade are all located in Spain. These sites all contained distinct Châtelperronian layers that yielded radiocarbon measurements from animal bones. La Guelga only yielded measurements from unmodified bones, while the rest of the sites had measurements from modified bones that were used for this analysis. Each of these sites provided radiocarbon data that provides insight into the chronology of the Châtelperronian, but they all lacked radiocarbon measurements from Neanderthal skeletal remains.

Chapter 3

Results

Direct Neanderthal Measurements

The calibrated radiocarbon dates from Neanderthal skeletons are shown in Figure 1. OxA-X-2687-57 is the oldest date ranging between 54,895-42,162 BP (95.4% probability).

MAMS-16562 is the youngest date ranging from 39,731-39,075 BP (95.4% probability). Using the Difference() command between these two measurements resulted in an 85.4% probability that the two dates are 6,560 to 13,353 years apart and a 10.0% probability that the measurements were 14,155-17,042 years apart (Figure 4).

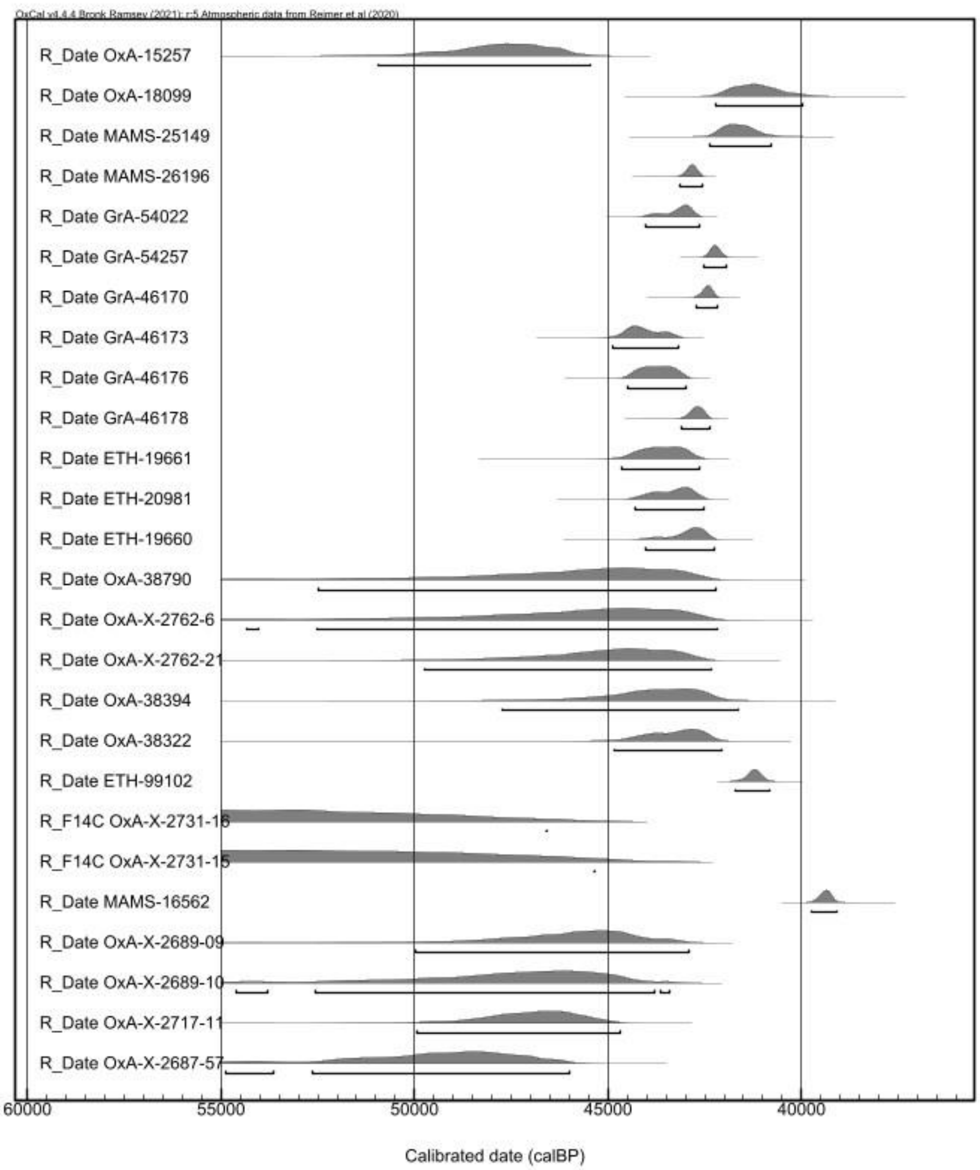

Figure 3. The 95.4% probability calibration ranges for the dates for the measurements from Neanderthal skeletons.

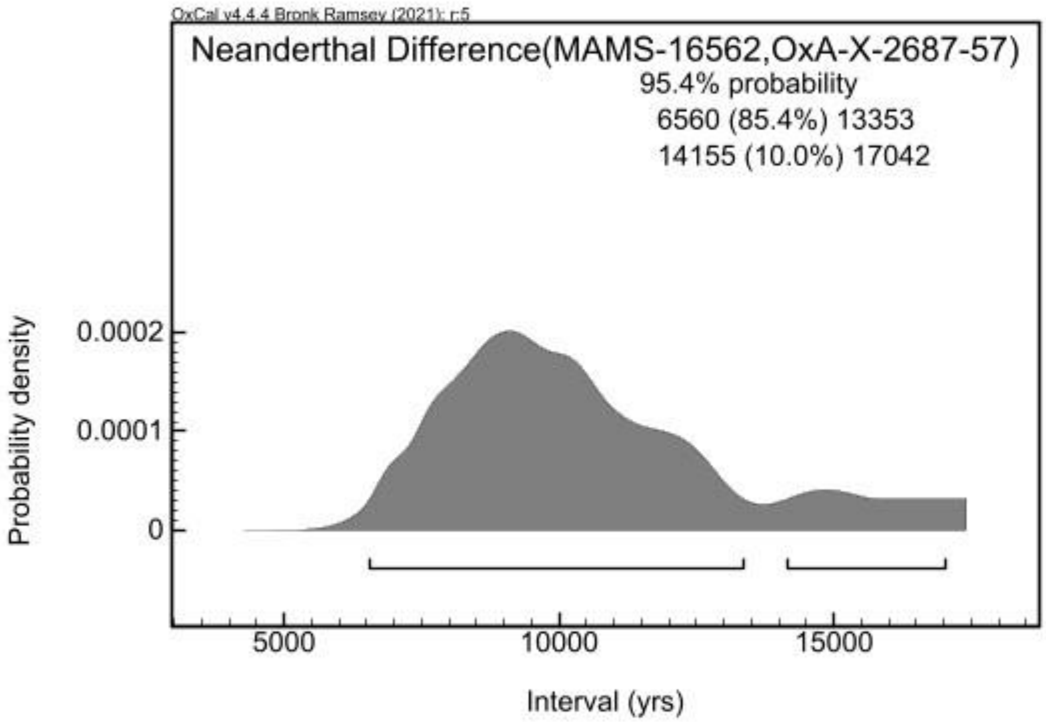

Figure 4. Results of the Difference() calculation between the youngest and oldest direct Neanderthal dates.

Châtelperronian Measurements

The youngest calibrated Châtelperronian dates from each of the selected sites are shown in Figure 5. Grotte du Renne's oldest calibrated date was EVA-33 which ranged from 44,599-43,144 BP (95.4% probability). The youngest calibrated date at Grotte du Renne was EVA-54 which ranged from 41,885-40,292 BP (95.4% probability). The calculated difference between these two measurements with a 95.4% probability is between 2,305-4,502 years. The youngest and oldest measurements from La Ferrassie were MAMS-17585 and MAMS-21206. Their date ranges with a 95.4% probability fall between 37,080-36,369 BP and 44,623-43,042 BP respectively. Les Cottes' youngest and oldest calibrated dates were composite dates of EVA-11/OxA-V-2381-53 and EVA-5/OxA-V-2381-51. The age ranges of these dates with a 95.4%

probability are 41,735-40,910 BP and 45,647-44,466 BP. La Quina Aval's youngest and oldest calibrated dates were OxA-21707 and OxA-21706. The 95.4% probability date ranges for those measurements are 43,830-41,224 BP and 44,576-42,121 BP. OxA-27958 is the only measurement from La Guelga and has a 95.4% probability date range of 45,660-42,312 BP. Labeko Koba's youngest and oldest calibrated dates were OxA-22560 and OxA-22562 with 95.4% probability date ranges of 41,484-38,761 BP and 44,754-41,976 BP. The youngest and oldest calibrated dates from Cassenade were OxA-31479 and OxA-31476, with respective 95.4% probability date ranges of 41,484-38,761 BP and 44,754-41,976 BP. The results of the difference calculation for the youngest and oldest date for each of the sites with more than one measurement are shown in Figure 6.

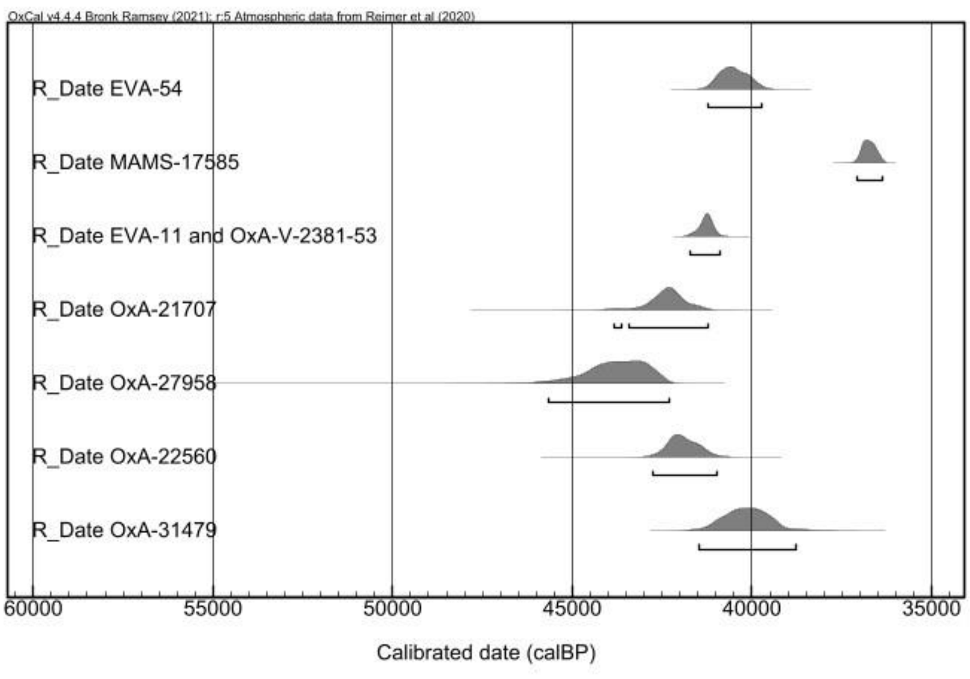

Figure 5. The youngest calibrated Châtelperronian dates from each of the sites. Measurements from top to bottom are from Grotte du Rene, La Ferrassie, Les Cottes, La Quina Aval, La Guelga, Labeko Koba, and Cassenade.

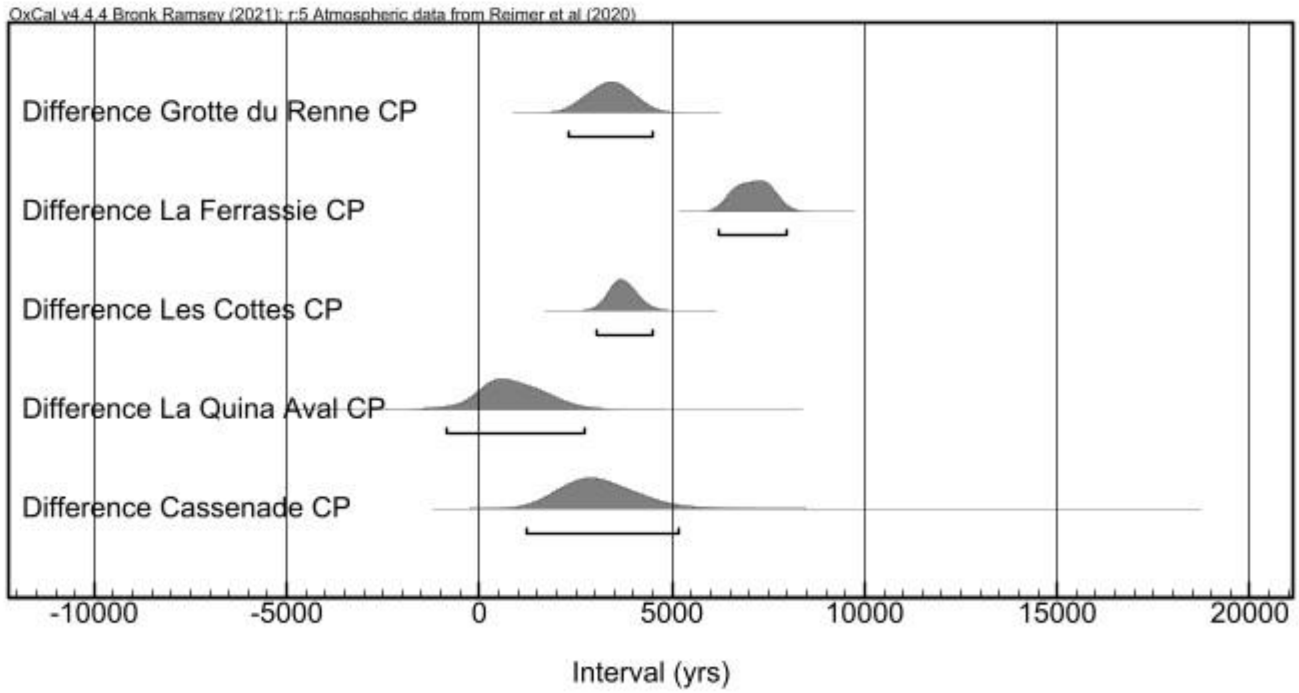

Figure 6. 95.4% probability difference between the youngest and oldest dates at the sites of Grotte du Renne, La Ferrassie, Les Cottes, La Quina Aval, and Cassenade.

Neanderthal and Châtelperronian Site Based Difference Calculations

The sites of Grotte du Renne, La Ferrassie, and Les Cottes all contained Châtelperronian and Neanderthal Radiocarbon measurements. The Difference() command was used to compare the youngest Châtelperronian measurement and the youngest Neanderthal measurement at each site. The Difference() command yielded a 95.4% probability that the difference between EVA-54 and the direct Neanderthal measurement MAMS-25149 was -1- 2,238 years (Figure 7). For the site of La Ferrassie, the Difference() command yielded with a 95.4% probability that the difference between MAM-1758 and the direct Neanderthal measurement ETH-99102 was 3,941-5,056 years (Figure 8). The Les Cottes calculated difference between the composite measurement EVA-11/OxA-V-2381-53 and the direct Neanderthal measurement MAMS-26196 was 1,029-2,064 years (Figure 9).

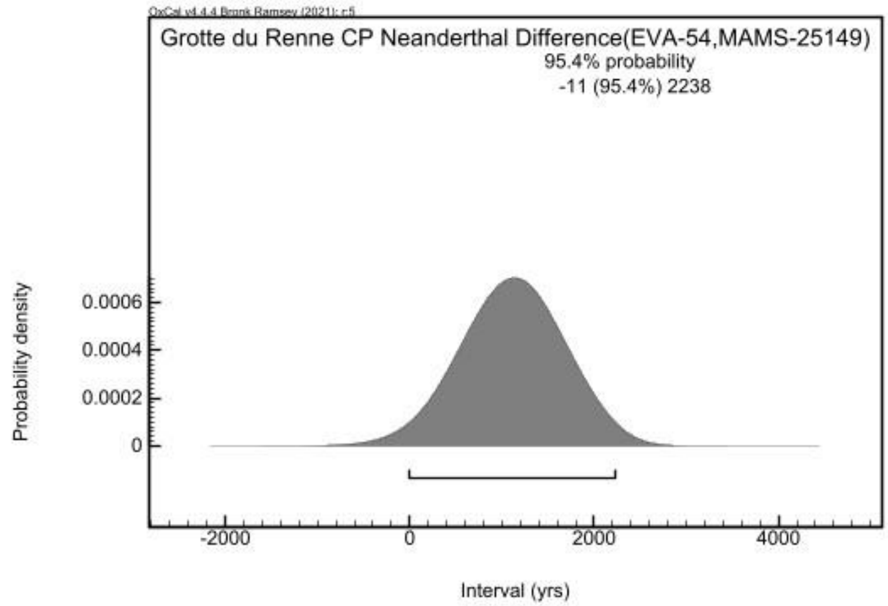

Figure 7. Results of the Difference() calculation between the youngest Châtelperronian and direct Neanderthal measurements at the site of Grotte du Renne.

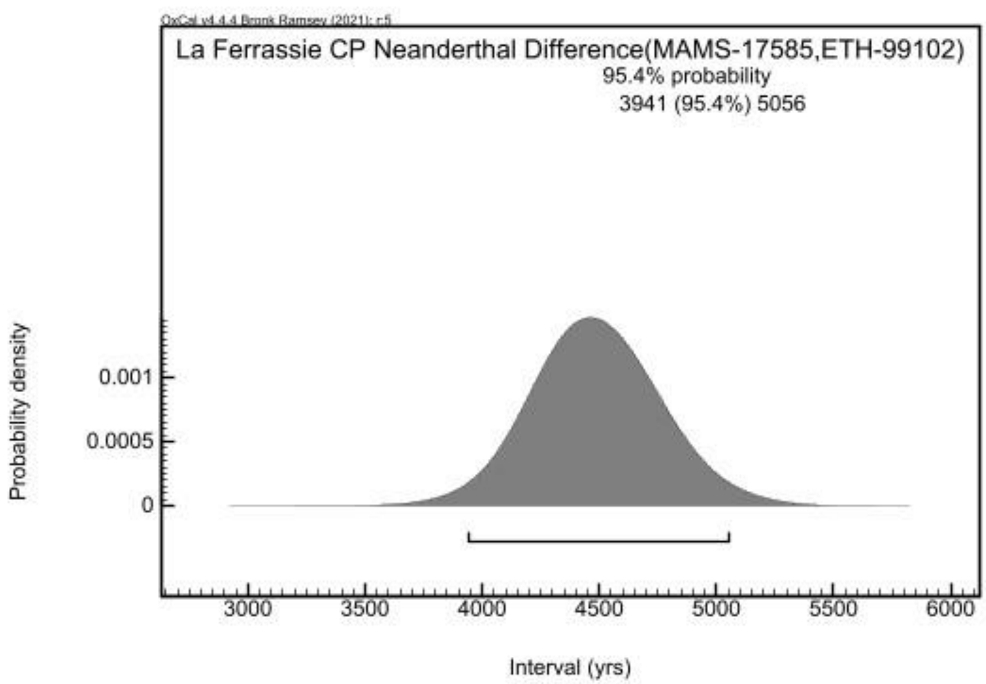

Figure 8. Results of the Difference() calculation between the youngest Châtelperronian and direct Neanderthal measurements at the site of La Ferrassie.

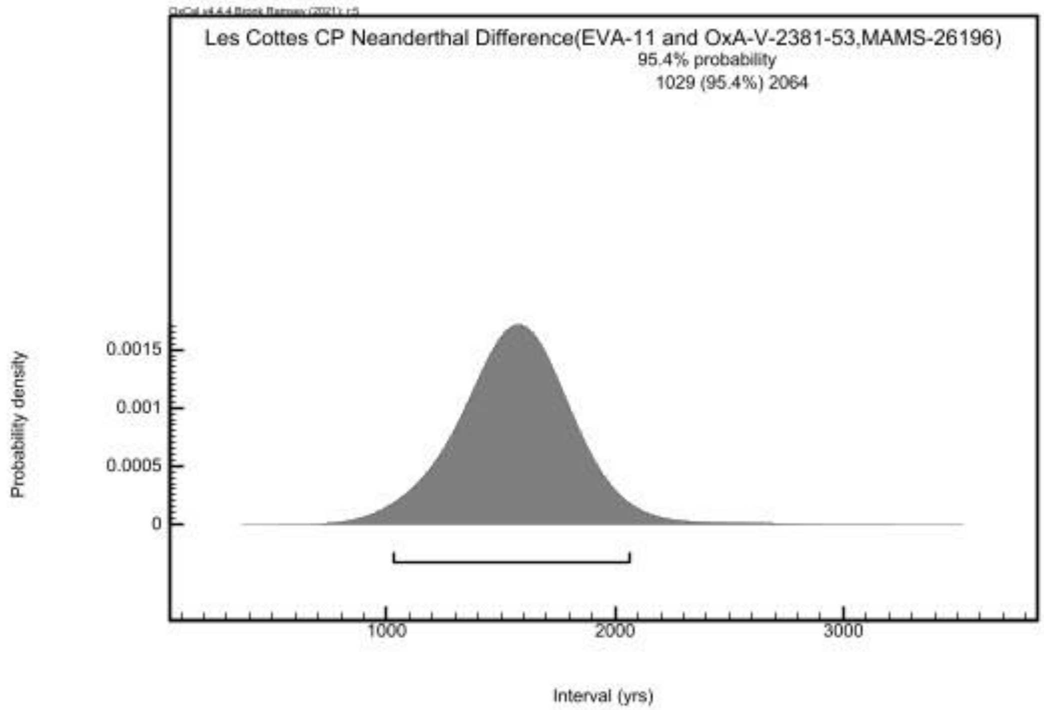

Figure 9. Results of the Difference() calculation between the youngest Châtelperronian and direct Neanderthal measurements at the site of Les Cottes.

Overall Neanderthal and Châtelperronian Difference Calculations

The Difference() command was used to compare the youngest direct Neanderthal measurement to both the youngest overall Châtelperronian measurement and the youngest Châtelperronian measurement from anthropogenically modified bone. The youngest Châtelperronian measurement MAMS-1758 was found with a 95.4% probability to have a 2,150 to 3,146 difference from the youngest Neanderthal measurement in the dataset MAMS-16562 (Figure 10). MAMS-16562 had a 95.4% probability difference of -624 to 2165 years from the youngest Châtelperronian measurement from anthropogenically modified bone OxA-31479 (Figure 11). OxA-31479 comes from marked animal bone from the site of Cassenade.

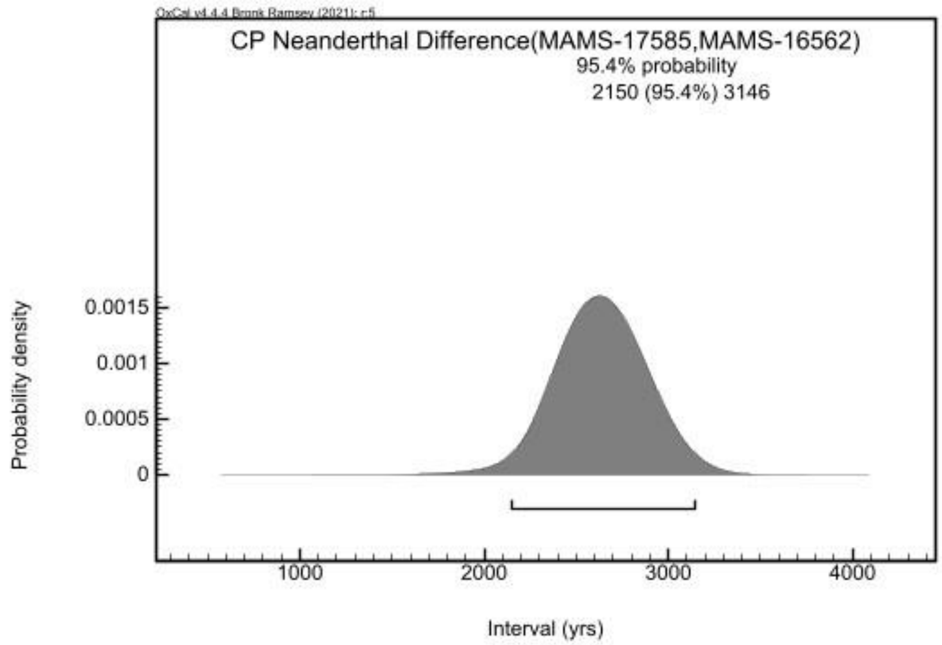

Figure 10. Results of the Difference() calculation between the youngest Neanderthal and Châtelperronian measurements in the dataset.

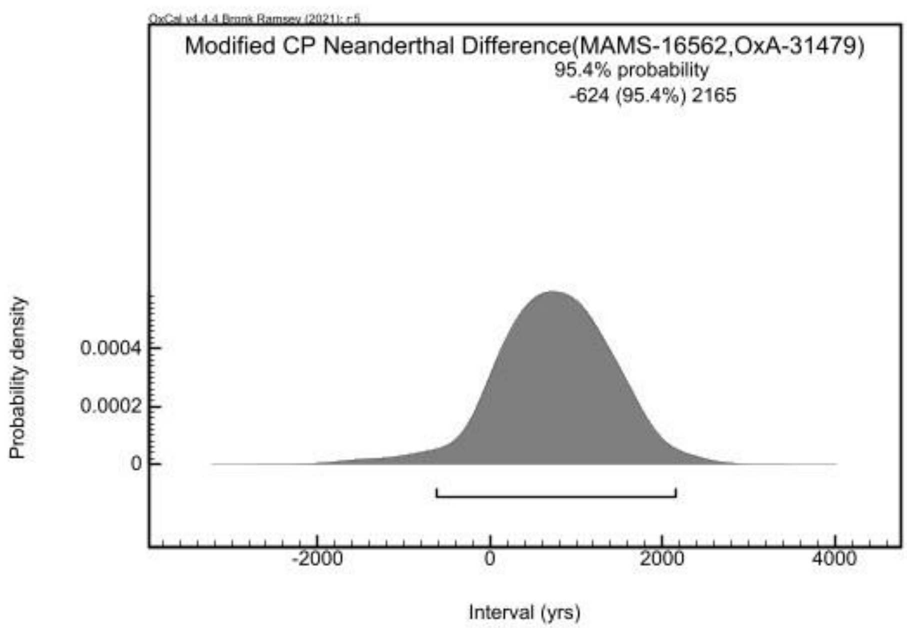

Figure 11. Results of the Difference() calculation between the youngest Neanderthal and Châtelperronian measurement from modified bone in the dataset.

Chapter 4

Discussion

The results presented in Chapter 3 are relevant to discussions about understanding the timing of the end of the Neanderthals, Neanderthal occupation-temporality, and the usefulness of radiocarbon dating. Both the compiled radiocarbon dates from directly dated Neanderthal remains and Châtelperronian material culture provide insights into these topics. Using the Difference() command to compare the direct Neanderthal radiocarbon dates to the Châtelperronian chronology demonstrates a close temporal relationship to the end of the Châtelperronian and the youngest directly dated Neanderthals. Though this close relationship is not a definitive indicator of Neanderthal associations with the Châtelperronian, this relationship has important implications regarding how both the direct Neanderthal and Châtelperronian radiocarbon measurements are understood in the greater discussion of the timing of the end of the Neanderthals.

Timing of the End of The Châtelperronian and Neanderthals

Comparing the Châtelperronian and Neanderthal measurements on both a site-based and general basis yielded similar results. The Châtelperronian measurements both predate and postdate the directly dated Neanderthal measurements at the sites (Grotte du Renne, La Ferrassie, and Les Cottes) that include both Châtelperronian and directly dated Neanderthal remains, which supports the attribution of the Châtelperronian to the Neanderthals. The oldest Neanderthal measurements on an overall level predate the Châtelperronian but do not postdate it. This is to be expected as the Neanderthals occupied the earlier layers while AMHs indisputably occupied the later layers. Though these findings alone do not definitively attribute the Châtelperronian to the

Neanderthals, the close temporal relationship between the last Neanderthals and the Châtelperronian demonstrated by this study generally supports their association. The ongoing debate about the stratigraphic relationship of materials at the key Châtelperronian sites continues to question the interpretations of the radiocarbon data and makes definitive attribution impossible at this point (Hublin et al. 18743).

The recent finding of possible AMHs remains in the Châtelperronian layers at Grotte du Renne (Gicqueau et al. 1-3, 10) cast further questions on which hominins are the true creators of Châtelperronian material culture. With further doubts being cast on Neanderthal occupation of the Châtelperronian, the results of the Difference() calculations between the Châtelperronian and direct Neanderthal measurements become more important in understanding the true timing of the end of the Neanderthals. If the Châtelperronian is assumed to have been occupied by the Neanderthals it generally places their end as a more recent event than what the direct Neanderthal measurements establish. The youngest Châtelperronian measurement in this study (MAMS-17585) post-dates the youngest direct Neanderthal measurement Neanderthal (MAMS-16562) by 2,150-3,146 years with a 95.4% probability (Figure 10). The youngest modified Châtelperronian measurement (Oxa-31479) is -624-2,165 years older than MAMS-16562 (Figure 11). Though this overall comparison is useful in determining how much difference there is between the overall story of the direct Neanderthal and Châtelperronian measurements, the site-based difference calculations are more useful as the materials are from the same location. Overall, at these sites, the directly dated Neanderthal measurements were -11-5,056 years older with a 95.4% probability (Figures 7-9). If the site of La Ferrassie is excluded this difference decreases to -11-3,146 years. Grotte du Renne, the site with the least difference had only a -11-2,238 year difference between its direct Neanderthal and youngest Châtelperronian measurements (Figure 7). On both a general and site-based level the differences between the Châtelperronian and direct Neanderthal measurements are on average just a few thousand years which is significant considering the span of Neanderthal occupation in Eurasia and the large probability distributions of the ancient radiocarbon measurements. Additionally, the two complied datasets broadly support the view that Neanderthals were no longer present by ~40,000 years ago.

Neanderthal Occupation Habits

The dating of materials found in the Châtelperronian implies that it spanned for thousands of years at the individual sites analyzed for this study (Figure 6), if it is assumed that Neanderthals occupied the Châtelperronian, then this becomes relevant to the discussion of how Neanderthals interacted with their environment. Similar to the Shaw et al. study pertaining to the idea of persistent place in the context of Neanderthals, the long span of the Châtelperronian and the preceding layers of the sites analyzed for this study demonstrate that Neanderthals returned to the same locations repeatedly for thousands of years. These sites that demonstrate repeated occupation could have offered shelter or contained key geographical features that stayed in the mind of Neanderthals, explaining their repeated occupation (Shaw et al. 1448-1450). The site of Les Cottes possesses evidence of Neanderthal activity that spans over 200,000 years (Shaw et al. 1448-14449). Les Cottes would not have been visible over long distances, suggesting this site was part of the long-term social memory of Neanderthals (Shaw et al. 14500). Occupation patterns of this site are dynamic and change with shifting climates, demonstrating Neanderthals altered their occupation habits with varying environmental conditions. This and the Shaw et al. study help paint the picture of how Neanderthals interacted with their surrounding and potentially, their long-term social memory.

Usefulness of the Dataset and Limitations

The radiocarbon dates compiled for this study provide data about the timing of the Châtelperronian and the last Neanderthals, but several limitations are present. In particular, there is a small sample size of direct dates from Neanderthal skeletal remains due to. 1) a general scarcity of Neanderthal remains, 2) issues with collagen preservations from Pleistocene bone samples, and 3) ethical issues that come from the destructive sampling required to produce a radiocarbon measurement. Moreover, a number of legacy Neanderthal radiocarbon measurements are not considered trustworthy due to carbon contamination (Deviese et al. 1-2). Probably the best-known case of radiocarbon contamination involving Neanderthal archaeology comes from radiocarbon measurements produced by the Oxford Radiocarbon Accelerator Unit with ultrafiltration methods. Adjustments to calibration curves have increased the precision and accuracy of dates, but the events of the MUPT are ancient enough to be at the backend of radiocarbon dating's range (~50,000 years). Calibrated radiocarbon measurements that are calibrated near the backend of the dating range (such as those used in this study) have large error margins that make resolving questions about the overlap between AMHs-Neanderthal occupation difficult to answer. The Châtelperronian sites analyzed for this study only represent a fraction of Neanderthal occupations in Eurasia, and there are many other sites that can lend their own insights into this topic. The large ranges of error witnessed in this study make it difficult to establish the relative temporal relationships between dated materials. The radiocarbon data compiled for this provide an approximate framework of when the Neanderthals and the Châtelperronian ended, but alone it does not establish what caused Neanderthal decline. Many other forms of contextual information and data must be used for possible causes to be determined. The close temporal relationship between the end of the Neanderthals with the rapid onset of climate change and interactions/admixture with AMHs establishes correlation between these events but is unable to establish causal relationships.

The limited data set and ongoing debates about Châtelperronian stratigraphy as discussed in Hublin et al. make it difficult to decipher if the Châtelperronian was exclusively the product of Neanderthals. Overall, this study demonstrates that radiocarbon dating is a very useful tool for establishing the approximate timing of the events of the MUPT though the need for other contextual data, complications of resolving stratigraphy, and limited data availability prevent it from definitively supporting one particular model of Neanderthal decline or who is responsible for the Châtelperronian.

Chapter 5

Conclusion

The MUPT was one of the most important events in human history that saw both the end of the Neanderthals and their replacement by AMHs. Radiocarbon dating Neanderthal remains and animal bones associated with Châtelperronian have allowed for an approximate timeframe of when the last Neanderthals walked the earth. This study supports current ideas about the end of the Neanderthals by showing that on a site based and the final directly dated Neanderthals all date to around 40,000 years (Stringer and Crete 403). This close timing to the arrival of AMHs (c. ~60 Ky BP) reinforces the correlation between AMHs' arrival and Neanderthal decline. Additionally, the dating of Neanderthal remains and comparing that to Châtelperronian site chronologies continue to support the notion that Neanderthals are associated with the Châtelperronian, though more work must be done to resolve questions of stratigraphy. More archaeological material such as hominin remains must be recovered from Châtelperronian layers to better resolve the question of which hominin should be attributed to the Châtelperronian. The association of the Neanderthals to the Châtelperronian is important to the discussion about Neanderthal symbolic capabilities as many cultural artifacts such as body ornaments are found in Châtelperronian layers (Hublin et al. 18743). Moreover, the timing of overlap between Neanderthals and Homo sapiens has intriguing implications regarding cultural transmission potentially reflected in Châtelperronian assemblages. (Hublin et al. 18743). There is still much work that will need to be done in the future in resolving questions pertaining to the Châtelperronian and the decline of the Neanderthals. Until the debates around the stratigraphy of the Châtelperronian are resolved and more materials are discovered and dated, the true occupiers of these sites will continue to be debated. Likewise, more interdisciplinary research into almost every aspect of the Neanderthals is needed to better understand lingering questions about this population decline.

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Appendix

OxCal Code

```
Plot()
{
 Phase("Direct Neanderthal Dates")
 {
  R_Date("OxA-15257",45200,1100);
  R_Date("OxA-18099",36200,750);
  R_Date("MAMS-25149",36840,660);
  R_Date("MAMS-26196",39485,271);
  R_Date("GrA-54022",39870,400);
  R_Date("GrA-54257",37890,350);
  R_Date("GrA-46170",38440,340);
  R_Date("GrA-46173",41200,500);
  R_Date("GrA-46176",40690,480);
  R_Date("GrA-46178",39140,390);
  R_Date("ETH-19661",40360,760);
  R_Date("ETH-20981",39900,620);
```

```
 R_Date("ETH-19660",39240,670);
 R_Date("OxA-38790",41700,2300);
 R_Date("OxA-X-2762-6",41600,2400);
 R_Date("OxA-X-2762-21",41500,1800);
 R_Date("OxA-38394",39900,1700);
 R_Date("OxA-38322",39500,1100);
 R_Date("ETH-99102",36171,220);
 R_F14C("OxA-X-2731-16",0.00021,0.00199);
 R_F14C("OxA-X-2731-15",0.00109,0.00236);
 R_Date("MAMS-16562",34177,159);
 R_Date("OxA-X-2689-09",42700,1600);
 R_Date("OxA-X-2689-10",43900,2000);
 R_Date("OxA-X-2717-11",44300,1200);
 R_Date("OxA-X-2687-57",46200,1500);
 Difference("Neanderthal","MAMS-16562","OxA-X-2687-57");
};
Phase("Grotte du Renne")
{
```

```
R_Date("EVA-52",35980,432);

R_Date("EVA-53",36230,435);

R_Date("EVA-54",35380,390);

R_Date("EVA-55",36630,452);

R_Date("EVA-56",37710,533);

R_Date("EVA-44",39280,351);

R_Date("EVA-46",39930,361);

R_Date("EVA-47",39750,360);

R_Date("EVA-33",40970,424);

R_Date("EVA-34",40520,389);

R_Date("EVA-35",39240,341);

R_Date("EVA-36",37740,307);

R_Date("EVA-37",39450,340);

R_Date("EVA-38",36540,248);

R_Date("EVA-40",37510,275);

R_Date("EVA-41",38730,333);

R_Date("EVA-42",38070,311);

R_Date("EVA-43",39020,352);
```

```
 R_Date("EVA-23",36840,335);
 R_Date("EVA-24",38400,317);
 R_Date("EVA-25",36210,250);
 R_Date("EVA-26",39390,334);
 R_Date("EVA-27",40230,395);
 R_Date("EVA-28",40930,393);
 R_Date("EVA-29",35500,216);
 R_Date("EVA-30",37980,284);
 R_Date("EVA-31",39290,334);
 R_Date("EVA-32",36820,257);
 R_Date("EVA-48",39070,332);
 R_Date("EVA-49",40830,778);
 R_Date("EVA-51",39960,702);
 Difference("Grotte du Renne CP","EVA-54","EVA-33");
 Difference("Grotte du Renne CP Neanderthal","EVA-54","MAMS-25149");
};
Phase("La Ferrassie")
{
```

```
 R_Date("MAMS-16373",37380,390);
 R_Date("MAMS-17585",32450,130);
 R_Date("MAMS-21207",38910,390);
 R_Date("MAMS-25522",36590,390);
 R_Date("MAMS-25523",39000,510);
 R_Date("MAMS-21208",36300,300);
 R_Date("MAMS-25524",40770,650);
 R_Date("MAMS-21206",40890,500);
 Difference("La Ferrassie CP","MAMS-17585","MAMS-21206");
 Difference("La Ferrassie CP Neanderthal","MAMS-17585","ETH-99102");
};
Phase("Les Cottes")
{
 R_Date("EVA-11 and OxA-V-2381-53",36230,210);
 R_Date("OxA-V-2381-53",36410,450);
 R_Date("EVA-13 and MAMS-10824 and OxA-V-2382-46",38100,210);
 R_Date("EVA-12 and MAMS-10823 and OxA-V-2382-45",37360,610);
 R_Date("MAMS-10803",38540,270);
```

```
 R_Date("EVA-21 and OxA-V-2381-50",41070,300);
 R_Date("EVA-5 and OxA-V-2381-51",42360,370);
 Difference("Les Cottes CP","EVA-11 and OxA-V-2381-53","EVA-5 and OxA-V-2381-51");
 Difference("Les Cottes CP Neanderthal","EVA-11 and OxA-V-2381-53","MAMS-26196");
};
Phase("La Quina Aval")
{
 R_Date("OxA-21707",38100,900);
 R_Date("OxA-21706",39400,1000);
 Difference("La Quina Aval CP","OxA-21707","OxA-21706");
};
Phase("La Guelga")
{
 R_Date("OxA-27958",40300,1200);
};
Phase("Labeko Koba")
{
 R_Date("OxA-22560",37400,800);
```

```
 R_Date("OxA-22563",37800,900);
 R_Date("OxA-22561",38000,900);
 R_Date("OxA-22562",38100,900);
 Difference("Labeko Koba CP","OxA-22560","OxA-22562");
};
Phase("Cassenade")
{
 R_Date("OxA-31475",38400,900);
 R_Date("OxA-31476",39300,1100);
 R_Date("OxA-31477",36600,750);
 R_Date("OxA-31478",35850,700);
 R_Date("OxA-31479",34950,650);
 Difference("Cassenade CP","OxA-31479","OxA-31476");
};
Phase("Overall")
{
 Difference("CP Difference","MAMS-17585","EVA-5 and OxA-V-2381-51");
 Difference("CP Neanderthal ","MAMS-17585","MAMS-16562");
```

```
  Difference("Modified CP Neanderthal","MAMS-16562","OxA-31479");
 };
};
```