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RESEARCH

Stone Tools in Shifting Sands: Past, Present, and Future Perspectives on the Châtelperronian Stone Tool Industry

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Abstract

The Middle to Upper Palaeolithic transition in France and northern Spain reflects the transition from Neandertals to *Homo sapiens* and the emergence of novel cultural entities and standardised blade and bladelet technologies between ~ 55 and 40 thousand years ago. The Châtelperronian stone tool industry represents the first unambiguous appearance of Upper Palaeolithic technologies in this region, and is traditionally considered as representing a geographically isolated archaeological entity produced by late Neandertals. However, debate as to the makers and origin of this industry has been ever-present. In recent years, fuel has been thrown onto this discussion through (a) the demonstration that the association between Neandertal remains and Châtelperronian artefacts at the key site of Saint-Césaire could not be reliable, (b) the identification of an immature *Homo sapiens* pelvic fragment in association with Neandertal remains and Châtelperronian artefacts at the Grotte du Renne (Arcy-sur-Cure), and (c) the formulation of a disruptive hypothesis in which the Châtelperronian directly originates from the Early Upper Palaeolithic of the Levant. In conjunction with the increasing evidence for a protracted presence of *Homo sapiens* across Europe, these observations have led to the arrival of an inflection point for the competing interpretations concerning the origin and implications of this industry. In this paper, we provide a critical review of the Châtelperronian in light of the emerging data—taking into account technological, chronological, geographic, stratigraphic, and genetic perspectives. First we provide a detailed, three-part historiography of this industry and a modern, synthetic review of Châtelperronian lithic technology. Our review reinforces the fact that the Châtelperronian is a fully Upper Palaeolithic industry with no 'transitional' nor Initial Upper Palaeolithic-type technological features. Subsequently, we highlight a series of prospects, problems, and uncertainties which remain to be addressed in discussions concerning the origins, maker(s), and implications of the Châtelperronian and the onset of the Upper Palaeolithic in western Europe. Finally, we propose a few potential paths forward and call for an open and critical approach towards the re-conceptualisation of the Châtelperronian in the years to come.

Keywords Neandertals · Middle to Upper Palaeolithic transition · Lithic technology · Anatomically modern humans

Introduction

As is the case across much of Eurasia, the Middle to Upper Palaeolithic transition in France and northern Spain documents the progressive replacement of Neandertals by *Homo sapiens* in the region. Taking place between ~ 55 and 40 thousand years ago, it is from an archaeological perspective characterised by the emergence of several distinctive stone tool industries with an increasing focus on standardised blade and bladelet lithic technologies. Of these industries, the Châtelperronian—which represents the first unambiguous technological rupture with the Middle Palaeolithic in the region—is presently the only one which retains a Neandertal connection based on fossil-artefact associations (Bailey & Hublin, 2006; Hublin et al., 1996; Leroi-Gourhan, 1958; Welker et al., 2016). First identified over a century ago and thought to reflect the products of early European *Homo sapiens* (Breuil, 1909), the Châtelperronian was first strongly linked to Neandertals in 1979 through the discovery of a near-complete Neandertal skeleton associated with Châtelperronian artefacts at the site of Saint-Césaire (Lévêque &

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Vandermeersch, 1981). This led to the re-interpretation of this industry as being the product of local Neandertals and the search for a local technological origin of the Châtelperronian, which began earlier in the century (Breuil, 1911; Peyrony, 1948; Bordes, 1958, 1968, 1972; Mellars, 1973), continued through the 90 s and early 2000s—culminating in the formulation of two competing hypotheses for the origin of this industry within the local Mousterian (Farizy, 1990a, b;, 1992; Soressi, 2002, 2004, 2005). In between, the discovery and subsequent re-analysis of a suite of Neandertal remains from the key site of Grotte du Renne lent support to these models (Bailey & Hublin, 2006; Hublin et al., 1996; Leroi-Gourhan, 1958), but there was nevertheless a growing skepticism concerning both the relationship of this industry to the local Mousterian (Bordes & Teyssandier, 2011; Jaubert et al., 2011) and the reliability of the Neandertal-Châtelperronian associations (Bar-Yosef & Bordes, 2010). Nonetheless, a local Neandertal origin for the Châtelperronian remained the most commonly accepted model, eventually superseded by the idea that the 'Upper Palaeolithic' character of the Châtelperronian is the result of a diffusion of behaviors from intrusive *Homo sapiens* onto local late Neandertal populations (e.g. Mellars, 2010; Roussel et al., 2016; Ruebens et al., 2015; Soressi & Roussel, 2014).

The debate concerning the makers, origin, and implications of the Châtelperronian has since remained effectively at a standstill—as no alternative model has been proposed for this industry and the only hominin remains recovered from Châtelperronian assemblages have been those of Neandertals. Recently, this situation has changed. Firstly, the association between the Neandertal remains and Châtelperronian cultural material at the site of Saint-Césaire has been assessed as being unreliable (Gravina et al., 2018; Todisco et al., 2023). Secondly, the morphological identification of an immature *Homo sapiens* pelvic fragment in association with both Châtelperronian artefacts and Neandertal remains at the key site of Grotte du Renne presents a first empirical evidence that *Homo sapiens* were present in the region during the formation of Châtelperronian assemblages (Gicqueau et al., 2023). Thirdly, technological and chronological data has increasingly emphasised the intrusive character of the Châtelperronian in the Iberian peninsula (Rios-Garaizar et al., 2022). And, finally, the recent formulation of a disruptive model for the emergence of the Upper Palaeolithic in France and northern Spain has for the first time proposed an alternative source for the origin of this industry (Slimak, 2023). In simple terms, this model contends that the onset of the Upper Palaeolithic in this region—reflected by the Neronian, Châtelperronian, Protoaurignacian stone tool industries—has an explicit analogue in the Mediterranean Levant, and is indicative of a direct connection between these regions during the period between ~ 55 and 40 thousand years ago (*ibid.*).

The evolution of these local perspectives is only made more poignant when set against the backdrop of the broader context. Specifically, the identification of *Homo sapiens* remains in diverse archaeological contexts across Europe substantially earlier than was traditionally assumed. Between ~ 55 and 40 kya cal BP, *Homo sapiens* skeletal remains are now identified in association with the Lincombian-Ranisian-Jerzmanowician (LRJ) at Ranis (Germany) (Mylopotamitaki et al., 2024), the Initial Upper Palaeolithic (IUP) at Bacho Kiro (Bulgaria) (Hublin et al., 2020), and the Uluzzian at Grotta del Cavallo (Italy) (Benazzi et al., 2011), as well as the Neronian IUP at Grotte Mandrin—thought to date to somewhere between 58 and 52 kya cal BP (Slimak et al., 2022). In addition, we must add *Homo sapiens* remains dating to before ~ 40 thousand years, albeit lacking archaeological context, from Romania (Fu et al., 2015) and Czechia (Prüfer et al., 2021). Adding additional complexity to this emerging pattern is the fact that some of these individuals show evidence of a recent Neandertal ancestor—and in the 14 years since the publication of the Neandertal genome, not a single late European Neandertal has exhibited evidence of a recent *Homo sapiens* ancestor. However, the recent re-evaluation of a series of permanent, fully erupted Neandertal teeth from the site of La Cotte de St. Brelade (< 48 kya cal BP) indicate the presence of mixed features indicating a possible shared Neandertal and *Homo sapiens* ancestry (Compton et al., 2021). These insights from broader perspectives, although not directly related to the Châtelperronian, nonetheless create a new frame of reference from which the Châtelperronian needs to be viewed.

In this paper, we provide a critical review of the Châtelperronian in the light of emerging data and perspectives—taking into account technological, chronological, geographic, and stratigraphic considerations. To begin, we provide a three-part historiography of the Châtelperronian highlighting the evolution of perspectives and a step-wise, synthetic review of Châtelperronian lithic technology. Our review reinforces the distinctive and fully 'Upper Palaeolithic' character of this industry, and we subsequently provide a point-by-point discussion on some key issues we are facing regarding the construction of higher-level interpretations for the origins and significance of the Châtelperronian and, more broadly, the onset of the Upper Palaeolithic in this region. Finally, we highlight a few potential prospects for future work and end with a call for an open and critical approach to disentangling the implications of the Châtelperronian industry in the years to come.

A Local Problem (1909–2010): Initial Discovery, Neandertal Associations, and the Search for a Local Mousterian Origin

Unlike some other techno-complexes of the Middle to Upper Palaeolithic transition, the Châtelperronian industry represents a notably coherent and geographically restricted archaeological entity (Soressi & Roussel, 2014). A little over 40 secure Châtelperronian sites have been recognised in France and northern Spain throughout an arch which stretches around 300 km wide, and fits closely to the western half of the Massif central (*ibid.*). This distribution stretches from Burgundy in north-central France, and extends through south-west France to Cantabria in the west, and the south-eastern limit is marked by the Oriental Pyrenees. At present, no Châtelperronian assemblages have been identified east of the Rhône valley—although its northernmost limit has recently been extended to the site of Ormesson in the Paris basin (Bodu et al., 2017). Over the last decade, there has been substantial work aimed at refining the chronology of this industry and it is now widely accepted as belonging to a window of time between 44 and 40 kya cal BP (Djakovic et al., 2022; Hublin, 2015; Talamo et al., 2020)—and is always found inter-stratified between Mousterian (below) and Protoaurignacian (above) layers when they occur at the same site (Soressi & Roussel, 2014).

The Châtelperronian was originally defined by H. Breuil after a lithic industry found at La Grotte des Fées at Châtelperron (Breuil, 1909). Breuil emphasised the similarities between this assemblage and the Abri Audi type industry, later attributed to the Mousterian of Acheulean Tradition Type B (MTA-B). This similarity was based partly on the presence of 'backed knives', produced on elongated blanks, which were found in both sets of assemblages. Due to the 'Upper Palaeolithic' character of the technology (i.e. blades, retouched tool types), the Châtelperronian was initially considered an industry produced by early European *Homo sapiens* (Sonneville-Bordes, 1960). This perspective was eventually shaken by the surprising discovery of Neandertal skeletal material recovered from two key sites: Saint-Césaire (Lévêque & Vandermeersch, 1980) and Grotte du Renne at Arcy-sur-Cure (Hublin et al., 1996). At Saint-Césaire, one near-complete Neandertal skeleton (interpreted as being in secondary position) and some isolated teeth were discovered during excavations in the 1970s (Lévêque & Vandermeersch, 1980) (Fig. 5d). Taxonomic attribution of the Saint-Césaire skeleton was later confirmed, and the teeth were shown to display a Neandertal morphological signature (Bailey & Hublin, 2006). At Grotte du Renne, 31 isolated teeth, one temporal bone, and numerous fragmentary elements were recovered from the Châtelperronian layers (X–VIII), with most attributed to the lowermost layer (layer X) (Fig. 5a, b) (Leroi-Gourhan, 1958). The temporal bone was attributed to the Neandertal clade based on the morphology of the preserved inner ear—which is considered typical of Neandertal phenotypic morphology (Hublin et al., 1996). All but one tooth were assigned to the reference Neandertal group with posterior probabilities which range from 59 to 99.9% (Bailey & Hublin, 2006).

In addition to these surprising fossil discoveries, both personal ornaments and bone tools were identified in Châtelperronian assemblages—at the time further reinforcing the 'Upper Palaeolithic' character of this industry. At Grotte du Renne, Arcy-sur-Cure, 47 artefacts interpreted as personal ornaments were recovered from the Châtelperronian layers (layers X–VII) (Caron et al., 2011; D'Errico et al., 1998). These include perforated and/or grooved mammal teeth, bone fragments, and a fossil. Six pierced teeth were also recovered from the Châtelperronian levels at La-Grande-Roche-de-la-Plematrie, Quinçay, during the excavations campaign run by F. Leveque between 1968 and the early 1990s (Granger & Lévêque, 1997). A rich collection of bone tools was also recovered from the Grotte du Renne—including byproducts from their manufacture (D'Errico et al., 1998; d'Errico et al., 2003). Some of these preserved incisions which have been interpreted as decoration, and awls and points, were identified as being the most common typological categories (d'Errico et al., 1998, 2003).

Through the 1990s and early 2000s, on the back of the reported association between Neandertal skeletal remains and Châtelperronian cultural material, there was a continued search for the origin of the Châtelperronian within the local Mousterian. This eventually led to the formulation of two competing hypotheses: the first one based on stratigraphy proposing an origin of the Châtelperronian within the Discoide-Denticulate Mousterian (Farizy, 1990a, b, 1992), and the second one based on a technological and morpho-functional approach (Soressi, 2002, 2004, 2005) reinforcing the idea of an origin within the MTA-B Mousterian advanced on typological ground since the mid-twentieth century (Peyrony, 1948; Bordes, 1958, 1968, 1972; Mellars, 1973). For Soressi, the different techno-complexes appearing to occupy the final Middle Palaeolithic were contemporaneous rather than continuous and/or mutually exclusive and, when searching for a local origin of the Châtelperronian, the only possible candidate was the elongated production of the MTA Type-B—the only late Mousterian technology in south-west France characterised by intentional production of both elongated and backed flakes (Soressi, 2002, 2004, 2005). Ultimately, this model gained favourability amongst researchers due to the more pronounced typo-technological similarities between these sets of assemblages (i.e. laminar productions, 'backed knives'). At the time, the arguments

for a MTA-B origin of the Châtelperronian were summarised—in shorthand—as follows (Soressi & Roussel, 2014):

- Both industries share a spatio-temporally unique interest for retouched backed tools and naturally backed products.
- Both share a tendency towards elongated products, which is not found in any other late Mousterian industry.
- The geographic distribution of the Châtelperronian is effectively analogous to that of the MTA-B.

Meanwhile, there was a contemporaneous development of two competing, higher-level models for explaining the association between Neandertals and the 'Upper Palaeolithic' artefacts characterising the Châtelperronian (i.e. blades, bone tools, personal ornaments): an independent innovation model (D'Errico et al., 1998; Zilhao & d'Errico, 1999) and an acculturation model (Hublin et al., 1996; Mellars, 2005). The independent innovation model effectively proposed that the Châtelperronian represented an independent transition to the Upper Palaeolithic by late Neandertal groups without influence from incoming *Homo sapiens* (D'Errico et al., 1998; Zilhao & D'Errico, 1999). The acculturation model maintained the Neandertal attribution, but proposed that the behavioural novelties seen in the Châtelperronian were the result of some form of influence from early European *Homo sapiens* producing Upper Palaeolithic technologies onto local Neandertal populations (Hublin et al., 1996; Mellars, 2005). In the end, the latter hypothesis—in combination with a local origin of the Châtelperronian within the MTA-B—eventually became the most commonly accepted model, later supplemented with additional arguments (which are discussed further).

A Growing Lack of Consensus: Skepticism, Stratigraphic Revisions, Conflicting Data and Interpretations

In the following years, both the Neandertal-Châtelperronian associations and the local origin model(s) were met with increasing skepticism—leading to a widening lack of consensus. From a chrono-cultural perspective, ongoing revisions of stratigraphic sequences in south-west France created substantial stratigraphic and chronological distance between the Châtelperronian and the MTA Type-B (Jaubert, 2011). Specifically, it was argued that a Discoidal and possibly Levallois phase seem to separate the elongated production associated to the MTA Type-B from the Châtelperronian at sites where they occur together in south-west France (*ibid.*)—casting doubt on a relationship between the Châtelperronian and the elongated production characterising the MTA-Type B. Additionally, some posited that a period of pronounced carnivore activity seems to have occurred between the final Middle Palaeolithic (Discoide/Levallois) and Châtelperronian occupations in the same region (Discamps, 2011)—creating distance not only from the MTA-B but from the regional Mousterian as a whole. In effect, such revisions began to place increasing empirical pressure on a local origin model for the Châtelperronian as it had been traditionally formulated.

At the same time, the Neandertal-Châtelperronian associations at both the Grotte du Renne and Saint-Césaire were also subject to debate and re-evaluation (e.g. Bar-Yosef & Bordes, 2010; Caron et al., 2011; Gravina et al., 2018; Higham et al., 2010; Hublin et al., 2012). The first notable challenge in the past decades was put forward by Bar-Yosef and Bordes (2010), who argued that the Neandertal remains associated with the Châtelperronian layers at the Grotte du Renne may have resulted from natural and anthropogenic site-formation processes which reworked the underlying Middle Palaeolithic into the Châtelperronian levels. The authors argued that there is clear evidence of digging and levelling activities during the Châtelperronian occupations, including the digging of postholes, which affected and displaced the underlying Mousterian layer and subsequently led to an artificial mixture of Mousterian and Châtelperronian artefacts and skeletal remains at the site (*ibid.*). They highlighted that the Mousterian deposits in the rear and front sections of the cave are topographically higher than the earliest Châtelperronian levels (Bar-Yosef & Bordes, 2010)—and that the noted decrease of Mousterian-type artefacts and Neandertal teeth from the oldest to the youngest Châtelperronian layers aligns with the predictions expected from mixture of the strata (*ibid.*). Subsequent research, based on a series ($n = 31$) of inconsistent and variable AMS radiocarbon dates for the Châtelperronian layers at Grotte du Renne, effectively served as an extension to these arguments (Higham et al., 2010). The high degree of intra-layer variation was used to support the idea of admixture between the Châtelperronian, Mousterian, and Protoaurignacian levels at the site—again questioning the security and integrity of the fossil and artefact associations (*ibid.*).

The early to mid-2010s saw this debate continue: between those who were increasingly critical of a local, Neandertal origin for the Châtelperronian (e.g. Bar-Yosef & Bordes, 2010; Bordes & Teyssandier, 2011; Gravina & Discamps, 2015; Jaubert et al., 2011) and those who continued to stress a local Neandertal origin with new data and argumentation—from chronological, biological, and material perspectives (e.g. Caron et al., 2011; Hublin et al., 2012; Roussel et al., 2016; Ruebens et al., 2015; Soressi & Roussel, 2014; Welker et al., 2016). Firstly, the re-working hypothesis as proposed by Bar-Yosef and Bordes (2010), and subsequently strengthened by Higham et al. (2010), was met by the objections that (a) the uppermost Mousterian layers at the Grotte du Renne in fact yielded very few human remains in comparison to the

Châtelperronian layers and (b) the Neandertal remains are not only present in the lowermost Châtelperronian layers, but also in the uppermost (layer VIII) (Hublin et al., 2012). Secondly, the inconsistency in dates throughout the Châtelperronian sequence at Grotte du Renne (Higham et al., 2010) was then argued to be the result of low collagen yields in the samples selected for dating (Hublin et al., 2012)—with 35 new measurements performed with a different sampling strategy producing stratigraphically consistent dates (Hublin et al., 2012). A number of years later, a subsequent study provided molecular support that the human remains present in the Châtelperronian layers are indeed Neandertals, and additionally identified 28 new fragmentary specimens (Welker et al., 2016). Furthermore, in the meantime, the hypothesis of a local origin of the Châtelperronian from the elongated production characterising the MTA Type-B was supplemented with the argument that the transition from the latter to the former was likely the result of an external influence of incoming *Homo sapiens* producing Protoaurignacian technology onto local late Neandertals—based most notably on the description of bladelet production and retouch in the Châtelperronian of Quinçay (Roussel et al., 2016; Soressi & Roussel, 2014).

Around the same time, initial revisions of the chrono-cultural sequence at the key sequence of Le Moustier were further demonstrating the chronological and stratigraphic distance between the elongated production partly characterising the MTA-B and the Châtelperronian—and adding empirical validity to the separation of these entities by both Discoidal and Levallois phases (Gravina & Discamps, 2015). Going even further, these authors questioned the validity of the MTA-B industry as traditionally formulated—highlighting that the assemblages assigned to this facies derive from old excavations and the combination of features thought to characterise this facies are the result of artificial lumping (i.e. combination of biface production, elongated production etc.) (*ibid.*). The final challenge to the Neandertal-Châtelperronian association arrived from a re-evaluation of the key site of Saint-Césaire by some of the same authors (Gravina et al., 2018). Based on a taphonomic, spatial, and typo-technological re-assessment of the levels containing and bracketing the Neandertal skeleton at this site (Gravina et al., 2018), the authors argued that—based on the available evidence—the association between the Neandertal remains and the Châtelperronian and/or Mousterian deposits at the site cannot be considered reliable (*ibid.*).

Despite ongoing debate, by the end of the 2010s, one of the leading hypotheses for the emergence of the Châtelperronian (and the Upper Palaeolithic in the region) was that it reflected the result of some form of influence/interaction between local Neandertals producing regional MTA-B technology and incoming *Homo sapiens* producing Protoaurignacian technology (e.g. Hublin, 2015; Roussel et al., 2016; Ruebens et al., 2015; Soressi & Roussel, 2014). Developing contemporaneously, an alternative viewpoint had emerged which questioned both the local origin and the makers of the Châtelperronian—which facilitated the growing lack of scientific consensus characterising these years (Bar-Yosef & Bordes, 2010; Bordes & Teyssandier, 2011; Gravina & Discamps, 2015; Jaubert et al., 2011). Driven by irreconcilable perspectives on the relationship of this industry to the local Mousterian, the lack of an alternative origin, and no new paleoanthropological data for the authors of this industry—this debate effectively remained locked from the late 2010s until the early 2020s.

A Shift in Scale (2020–present): Continental Perspectives, New Paleoanthropological Data, and a Disruptive Model

In the most recent years, the growing lack of consensus has been to some extent disrupted by new data and evidence from both regional and inter-regional scales. Firstly, through increasing paleoanthropological evidence from across Europe which has demonstrated a protracted and widespread presence of *Homo sapiens* prior to ~ 42 kya cal BP, and associated with multiple distinct stone tool industries. As it stands today, in the period between ~ 55 and 40 kya cal BP, *Homo sapiens* skeletal remains are now identified in association with the Lincombian-Ranisian-Jerzmanowician (LRJ) at Ranis (Germany) (Mylopotamitaki et al., 2024), the IUP at Bacho Kiro (Bulgaria) (Hublin et al., 2020), and the Uluzzian at Grotta del Cavallo (Italy) (Benazzi et al., 2011), as well as the Neronian IUP at Grotte Mandrin—dating to somewhere between 58 and 52 kya cal BP (Slimak et al., 2022). In addition, *Homo sapiens* remains dating to before ~ 40 thousand years, albeit lacking archaeological context, have been recovered from Romania (Fu et al., 2015) and Czechia (Prüfer et al., 2021). On top of this, a number of these early *Homo sapiens* individuals have exhibited evidence for recent Neandertal ancestry in their nuclear genome (Fu et al., 2015; Hajdinjak et al., 2021).

At the regional perspective, relevant to this image is the fact that the Châtelperronian is now considered intrusive in the Iberian peninsula (Rios-Garaizar et al., 2022), and that an immature *Homo sapiens* pelvic fragment has recently been identified in association with both Châtelperronian artefacts and Neandertal remains at the Grotte du Renne (Gicqueau et al., 2023). This discovery represents the first evidence for an association between *Homo sapiens* and the Châtelperronian, as well as the first co-occurrence of Neandertal and *Homo sapiens* skeletal remains within the same archaeological context (layer) in any archaeological site across Europe. If supported by additional discoveries, this may—for the first time—demonstrate that *Homo sapiens*

were present in France during the formation of Châtelperronian assemblages between roughly 44 and 40 thousand years ago. Such a demonstration would effectively lend itself to two primary interpretative scenarios concerning the maker(s) of the Châtelperronian, at least in the case of the Grotte du Renne. Firstly, taking the co-occurrence of Neandertal and *Homo sapiens* remains in the Châtelperronian levels at face value, a scenario involving mixed groups and/or potentially hybrids. Secondly, given the important arguments concerning the integrity of the Châtelperronian levels at the Grotte du Renne (e.g. see Bar-Yosef & Bordes, 2010; Teyssandier, 2024), a scenario in which at least one of the hominin associations is unreliable—and the co-occurrence is instead artificial. In either case, it is clear that we are far from a clear resolution concerning the maker(s) of this assemblage—but the first identification of a possible *Homo sapiens* individual in a Châtelperronian context marks an important inflection point in the evolution of interpretative models surrounding this industry.

What is more clear today is that the Châtelperronian appears to represent an intrusive techno-cultural entity across its geographic distribution. As of the moment of writing, a connection between the Châtelperronian and the local late Mousterian has lost empirical strength and should no longer be accepted as the dominant model. Although indirectly, the preliminary identification of a *Homo sapiens* fossil remain in the Châtelperronian levels at Grotte du Renne lends support to the idea that some form of population turnover—whether by Neandertals, *Homo sapiens*, or a combination of both—is driving the techno-cultural rupture observed at the transition from the final Mousterian to the Châtelperronian across the region. To this effect, the recent formulation of a disruptive model in which the first stages of the Upper Palaeolithic in France have a direct analogue in the Early Upper Palaeolithic of the Mediterranean Levant has thrown fuel onto this fire (Slimak, 2023). In simple terms, this model proposes that the trajectory and character of the technological changes observed in France and northern Spain between ~ 55 and 40 kya cal BP have direct and explicit analogues in the Mediterranean Levant (*ibid.*)—possibly indicating a connection between the opposing ends of the Mediterranean Sea during the Middle to Upper Palaeolithic transition. In this model (Slimak, 2023), the Châtelperronian is proposed as reflecting a movement of *Homo sapiens* populations producing Northern Early Ahmarian technologies from the Levant to western Europe via a crossing or series of crossings of the Mediterranean Sea.

The inter-regional perspective this model highlights—i.e. a potential connection between opposing ends of the Mediterranean Sea during the MP-UP transition—creates, despite its speculative nature, a thought-provoking disruption on the debate surrounding the origins of the Châtelperronian which has otherwise remained effectively stagnant. This is especially the case when combined with the increase in paleoanthropological and genetic data suggesting a complex and protracted presence of *Homo sapiens* both within France and across Europe—and the potential overlap between these early *Homo sapiens* groups and local Neandertal populations at both scales (i.e. intra- and inter-regional) of observation (e.g. Compton et al., 2021; Djakovic et al., 2022; Hublin et al., 2020; Mylopotamitaki et al., 2024). Irrespective of its validity, the formulation of such a model effectively highlights the pronounced shifts in perspective that have been brewing over the last two decades of research on this topic. It is becoming increasingly more accepted that the Châtelperronian represents an intrusive technological entity (e.g. Rios-Garaizar et al., 2022; Teyssandier, 2024), which may have been underpinned by some form of demographic transformation involving *Homo sapiens* (Gicqueau et al., 2023). One logical consequence of this shift is the search for an inter-regional origin or 'source'—and the formulation and testing of alternative hypotheses for the emergence of the Upper Palaeolithic in this region. Whether or not the identification of a direct 'origin' of the Châtelperronian is even attainable is of secondary importance to the fact that a critical re-conceptualisation of the demographic and cultural mechanisms underpinning the appearance of this industry is needed. In effect, this latter statement largely summarises the state of the debate as we reach the end of 2024.

To help facilitate this re-conceptualisation, and comparisons with archaeological industries at a broader scale of observation, below we present a detailed, synthetic overview of the current knowledge on Châtelperronian lithic technology. The last such reviews were published nearly a decade ago (Ruebens et al., 2015; Soressi & Roussel, 2014) and, given the recent publication of some notable works which we consider important to this topic (e.g. Bodu et al., 2017; Bordes & Bachellerie, 2018; Michel et al., 2019; Rios-Garaizar et al., 2022), we feel that the an updated, integrative technological synthesis is timely. Finally, in light of the recent proliferation of work on the Initial Upper Palaeolithic complex, it seems necessary to clarify the 'taxonomic' position of the Châtelperronian within the evolving technological landscape.

An Updated, Synthetic Review of Châtelperronian Lithic Technology

Châtelperronian lithic technology is, in fact, one of the most well-studied stone tool industries occupying the 55–40 kya cal BP time window across Europe (Bricker & Laville, 1977; Boëda, 1991; Guilbaud, 1993; Pelegrin, 1995; Harrold, 2000; Connet, 2002; Bordes, 2003; Roussel & Soressi, 2006; Grigoletto et al., 2008; Bachellerie, 2011; Bordes & Teyssandier, 2011; Roussel, 2011; Soressi,

2011; Aubry et al., 2012, 2014; Baillet et al., 2014; Roussel et al., 2016; Bodu et al., 2017; Discamps et al., 2019; Rios-Garaizar et al., 2022). However, and likely in part due to this extensive research history, some aspects remain misunderstood and/or mischaracterised. Here, we combine primary data and observations from two Châtelperronian assemblages (Les Cottés, US 06 and Quinçay, En) with descriptions in the published literature to provide a detailed review of this technology. The review is presented following a synthetic structure which combines individual criteria into seven well-established analytical divisions of lithic *chaînes opératoires*: hammer type and striking gesture [1], core initialisation and configuration [2], striking platform management [3], blank production [4], core maintenance procedures [5], core discard [6], and targeted products and retouched tools [7].

In doing so, we have three more specific goals. The first is to present a critical and holistic image of the key signatures characterising Châtelperronian lithic technology when considered a whole. The second is to take some time to highlight the internal technological variability by examining intra-site behavioural specificities. Finally, the third is to point attention to a few diagnostic elements of the *chaine opératoire*—with particular attention to maintenance procedures—which we believe have been insufficiently stressed in the literature.

Hammer Type and Striking Gesture

Percussion techniques within the Châtelperronian can be generally summarised as reflecting the variable use of marginal—and to a lesser extent—internal percussion, utilising a mineral (i.e. stone) hammer. The generally thin striking platforms (~ 2–5 mm), frequent soft abrasion of the external platform edge, ~ 90 exterior platform angles, common occurrence of splintered bulbs (*esquillement de bulbe*), weakly developed bulbs of percussion, and low frequency of pronounced internal platform 'lips' are consistent of a marginal application of force using a soft-stone hammer for *plein debitage* (e.g. Pelegrin, 1995; Bachellerie, 2011; Roussel et al., 2016; Bodu et al., 2017; Rios-Garaizar et al., 2022; Rios-Garaizar et al., 2012; Michel et al., 2019; Aubry et al., 2012; Aubry et al., 2014). Internal hard-hammer percussion is reported, however, specifically for larger initialisation/maintenance products or the production of blanks for end-scrapers (Michel et al., 2019). With this said, some experimental work has criticised the unequivocal distinction between hard or soft stone hammers (Roussel et al., 2009). Taking this into account, a more cautious interpretation would be that Châtelperronian knappers generally utilised a marginal striking gesture and a percussor of mineral nature for primary debitage (*plein debitage*) phases.

Core Initialisation and Configuration

Large blocks or slabs, and also large flakes, appear to be preferentially selected for Châtelperronian blade production. Given the character of discarded cores, it is likely that morphologies which afford the unproblematic installation of a wide and flat flaking surface are particularly desirable. Early-stage Châtelperronian blade cores often show an installation of a one-sided crest (Fig. 1), generally on a narrow face, prepared with unidirectional transverse removals which extend onto an adjacent wide surface (Bachellerie, 2011; Bodu et al., 2017; Roussel et al., 2016). Two-sided starting crests also occur, but appear to be less frequent (Fig. 1b) (e.g. Connet, 2002). The second wide and narrow faces often show minimal preparation, although postero-lateral cresting does feature on some discarded blade cores. This shaping procedure often produces initialised cores with an asymmetric cross-section and the first generation of crested blades also often display this asymmetry (i.e. show laterally steeped cross sections). Bladelet cores, which are produced on small blocks or large flakes (*debitage sur tranche*), can show very similar initialisation procedures (asymmetric configuration of narrow and wide surface)—and crested lamellar elements (< 13 mm) occur in some Châtelperronian assemblages (Bachellerie, 2011; Roussel et al., 2016; Rios-Garaizar et al., 2022) (Fig. 1a). It must be noted however that there is a degree of variability in the character of bladelet core initialisation and configuration between assemblages—with some showing minimal preparation procedures (Bodu et al., 2017).

Striking Platform Management

The installation of a striking platform through the detachment of a large flake in the axis of the first debitage surface makes it possible to control the desired angulation, which is revived through the detachment of subsequent partial or total core tablet products. The angle between the platform(s) and the flaking surface(s) is nearly always between 75 and 90° (Bachellerie, 2011; Bodu et al., 2017; Rios-Garaizar et al., 2022; Roussel et al., 2016) (Fig. 2a, b). Two opposing platforms appear to be relatively frequently opened in early stages of core reduction/initialisation (Bachellerie, 2011; Bodu et al., 2017). This is made evident by large, overshot blades which preserve an opposing (and often separated) platform on their distal end (Fig. 3b–c). However, exclusive unidirectionality is reported at some sites (e.g. Michel et al., 2019). Platform faceting is rare, if not entirely absent, from debitage—although a small degree of platform faceting is occasionally reported (e.g. Rios-Garaizar et al., 2012). More commonly, platforms are almost exclusively unmodified (Fig. 2a–b), excluding the relatively common occurrence of a soft abrasion on the external platform edge—likely related to the use of a soft-stone percussor. The maintenance

Fig. 1 Châtelperronian crested blades (b–d) and bladelet (**a**) from initialisation/configuration stages. One-sided crests (a, c–d) and two-sided crest (**b**). Note the lateral-steeped cross-section (**c**). Artefacts are from the Châtelperronian of Quinçay (c, d) and Les Cottés (a, b)

of a near-perpendicular (75–90°) exterior platform angle, through successive tablet removals (total and partial), is a common feature however—with acute exterior platform angles on both cores and debitage being very uncommon (Bachellerie, 2011; Bodu et al., 2017; Connet, 2002; Michel et al., 2019; Porter et al., 2019).

Blank Production

Large- and medium-sized blades are detached following a sub-parallel reduction method most often from the wide flaking surface of a core (e.g. Connet, 2002) (Fig. 3a). However, the narrow surface may sometimes play a secondary role, and cores may be entirely re-oriented at the very late stage of reduction (e.g. Roussel et al., 2016) (Fig. 3a). Some cores, as at Quinçay and Les Cottés, show a debitage progression on as many as three distinct (i.e. non-continuous) surfaces—often one wide and two narrow—producing a distinct rectangular cross-section in core morphology (Roussel, 2011; Roussel et al., 2016).

When blades are detached from two opposed striking platforms, blank production commonly follows short series of unidirectional removals from a single platform before a switch to an opposed or opposed and separated platform. In this sense, when reduced using two opposed platforms, Châtelperronian blade reduction does not reflect true intersected bidirectionality, but rather a form of alternating unidirectionality (Roussel, 2011). Within the debitage, this procedure is witnessed in the co-existence of blanks with unidirectional and bidirectional dorsal scar patterns—the latter of which are often in lower proportions (Bachellerie, 2011; Bodu et al., 2017; Rios-Garaizar et al., 2022; Roussel, 2011)—as well as in overshot blades preserving an opposing striking platform (Fig. 3b–c). This is not ubiquitous, however, with some assemblages indicating the use of unidirectional reduction methods (Grigoletto et al., 2008; Michel et al., 2019). Blanks with lateral-steeped cross-sections are often detached from either (a) the intersection between two flaking surfaces or (b) the intersection between the flaking surface and the core edge or back (during late-stage reduction). In some cases, and likely during the later stages of blank production, reduction is shifted to an opposed and separated striking platform prior to the discard of the core (e.g. Roussel et al., 2016) (Fig. 3a).

Small blade and bladelet production (Fig. 2b, Fig. 4a) is to some extent variable, evidenced by the presence of at least three modalities leading to the production of small laminar elements: 'simple' burin-type cores on the edge of flakes and blades (Aubry et al., 2012, 2014; Bodu et al., 2017; Pelegrin, 1995; Roussel, 2011), prismatic/volumetric bladelet cores (Rios-Garaizar et al., 2022; Roussel, 2011; Roussel et al., 2016), and a continuum of reduction from blades to bladelets on the same core (Bachellerie, 2011; Floss et al., 2016). For burin-type cores, products are initially detached transversally from the distal edge of a thick flake, with production often progressing to the ventral face of the flake or

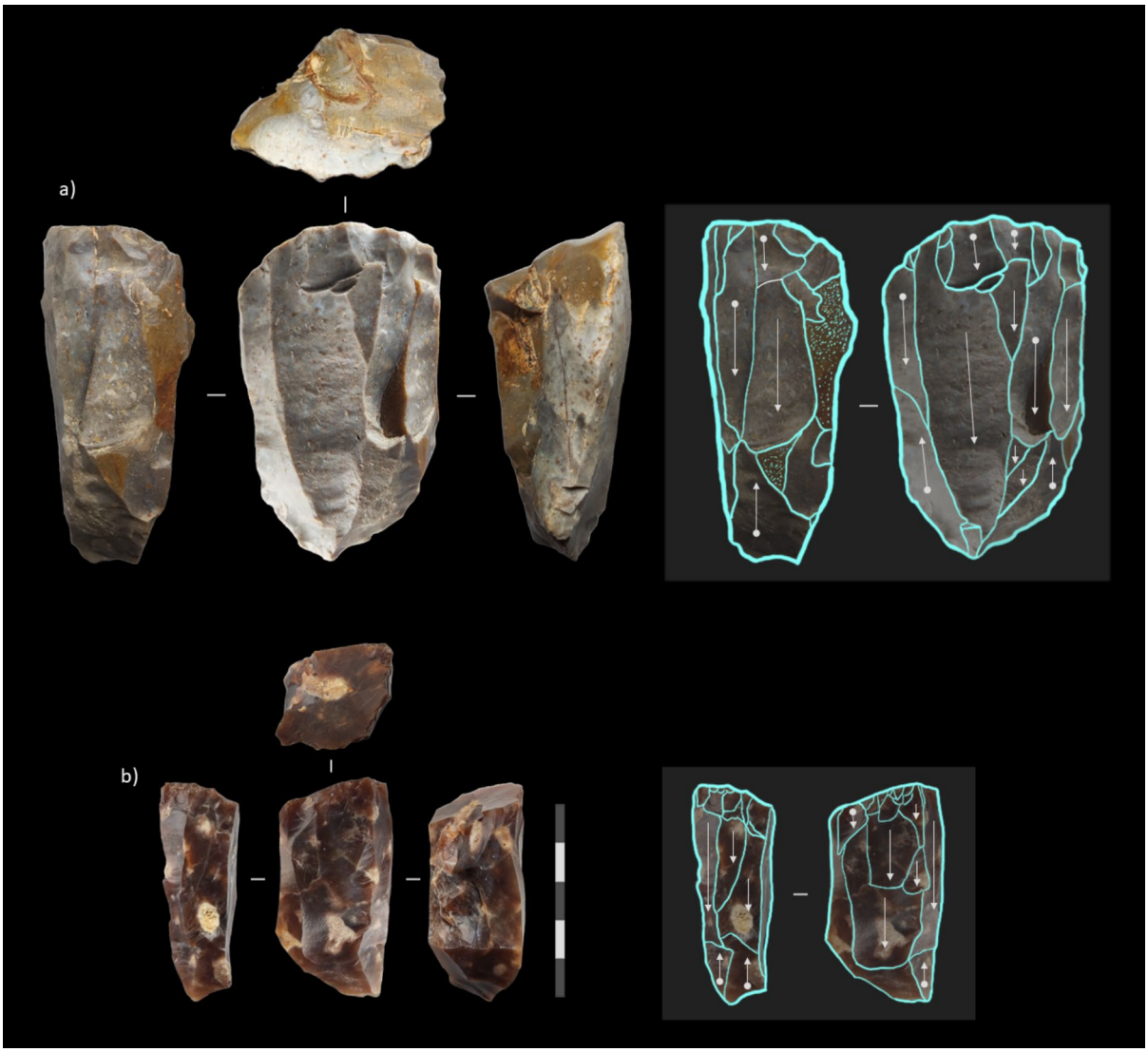


Fig. 2 Châtelperronian blade (**a**) and bladelet core (**b**) showing postero-lateral cresting, plain platforms, and EPAs of ~ 75–80°. Note the highly similar configuration and asymmetrical cross-sections of the cores. Opposed and opposed and separated striking platform have been used for both maintenance and debitage procedures. Artefacts are from the Châtelperronian of Quinçay (a) and Les Cottés (b)

blade (e.g. Bodu et al., 2017; Pelegrin, 1995). These cores generally however show a relatively low degree of productivity, and are often abandoned due to recurrent hinge fractures after a short series of removals. This may be related to the steep angle between the platform and flaking surface in combination with an insufficiently marginal striking gesture.

Volumetric bladelet cores are generally more productive and mirror, to a notable extent, the method used for large-medium blade reduction (Bachellerie, 2011; Bodu et al., 2017; Pelegrin, 1995; Roussel et al., 2016). Production similarly appears to be aimed at the obtention of straight or slightly curved sub-parallel bladelets (Fig. 4a). This appears to be the case in almost all Châtelperronian assemblages where bladelet production has been reported. One notable exception to this is a highly productive, convergent bladelet core from the recently published site at Aranbaltza, Spain, which—for the moment—remains largely unique within well-described Châtelperronian assemblages (Rios-Garaizar et al., 2022).

Core Maintenance Procedures

Blade production is maintained through the use of second-generation crested blades, debordant blades, core tablet removals, and laminar rejuvenation flakes. Neo-crested blades are a common maintenance procedure applied throughout core reduction to restore lateral convexities (Fig. 5b–e). Similar to initial crests, these are generally

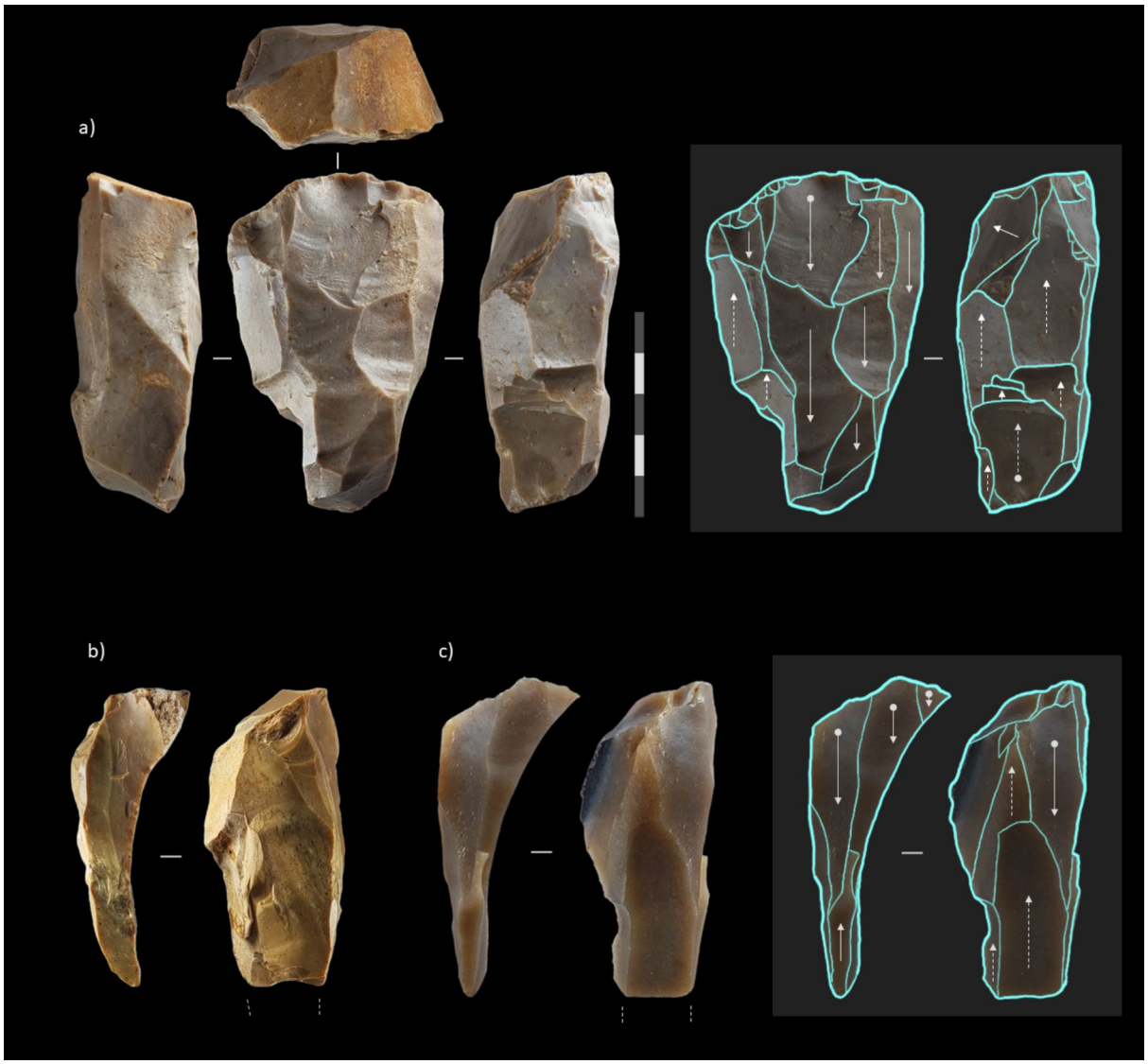


Fig. 3 Discarded Châtelperronian blade core (**a**) and two overshot blades preserving an opposed and separated striking platform (**b**–**c**). Note the shift to an opposed and separated striking platform for the final removals (dashed arrows) and the internal striking gesture applied to detach the last series of products (including the overshot blades themselves). Artefacts are from the Châtelperronian of Quinçay (a–b) and Les Cottés (c)

installed at the intersection of two flaking surfaces—producing a crested blade with an acute triangular cross-section. Neo-crested blades can show substantial size variability, indicating that this may be a recurrent maintenance procedure throughout the reduction of a core. The removal of non-crested debordant blades with a laterally steeped cross-section likely fulfilled a similar role when cresting was not required to alter the angle and morphology of the removal (Fig. 5f).

The presence of partial or complete tablet removals on blade cores shows that rejuvenation of the striking platform was a relatively common maintenance procedure (Fig. 5a), an observation which is supported by the identification of core tablets corresponding to blade production in almost all Châtelperronian assemblages. For example, at Les Cottés, maintenance tablets are numerous—and are either detached frontally or, less often, laterally to the main flaking surface. The counter-bulbs present on the lateral edges of the tablets indicate debitage sequences of wide blades, narrow blades, and bladelets.

Laminar rejuvenation flakes are large flakes removed from the wide flaking surface of blade cores, generally with an internal striking gesture, after the surface has become flattened due to the extraction of several blades (e.g. Roussel et al., 2016) (Fig. 6c). This procedure removes nearly the entire flaking surface, serving

Fig. 4 Bladelets (**a**) and blades (**b**) from *plein debitage* production stages. All bladelets show unidirectional dorsal scars, while the blades show both bidirectional and unidirectional patterns. All artefacts are from the Châtelperronian of Quinçay, except for the lower left blade

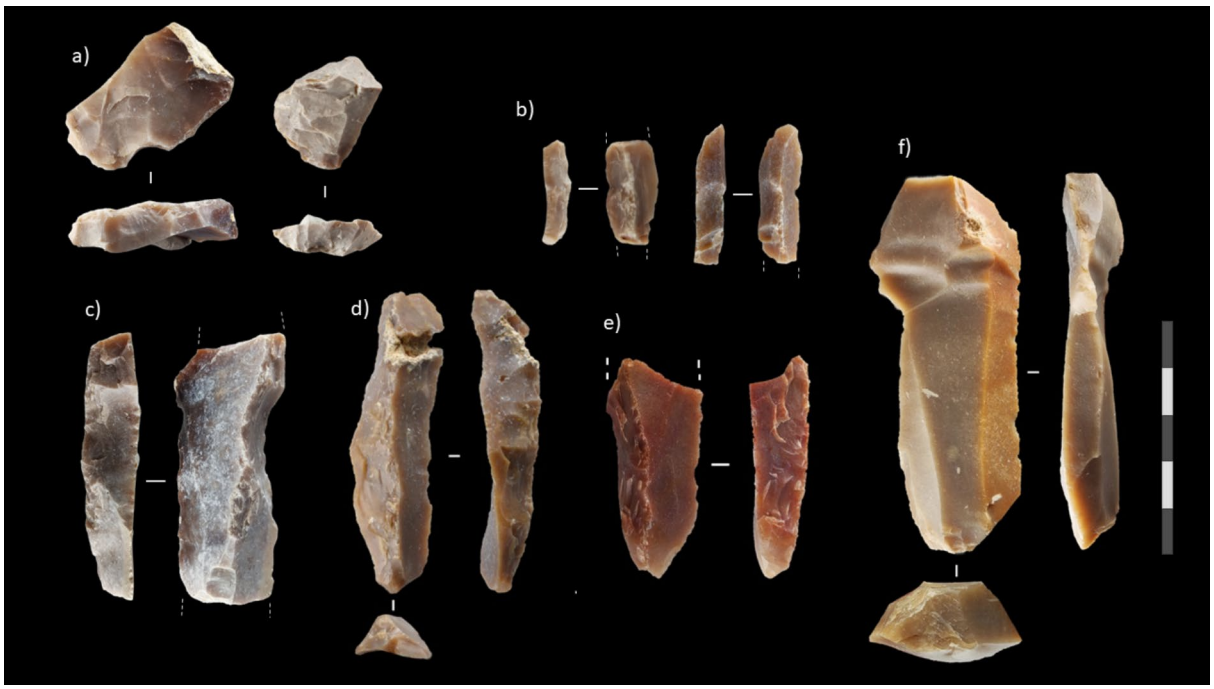


Fig. 5 Products relating to maintenance interventions. **a** Core tablet removals, **b–e** neo-crested products of various sizes, **f** large debordant blade. Artefacts are from the Châtelperronian of Quinçay (**d**) and Les Cottés (**a–c**, **e–f**)

to construct new transversal convexities. Following the detachment of this flake, an asymmetrical blade is removed from the intersection of the narrow and wide surface and blade production is recommenced. These products are often converted into end-scrapers, as is evident by the presence of numerous laminar negatives on the dorsal face of many Châtelperronian end-scrapers (Baillet et al., 2014; Roussel et al., 2016) (Fig. 6c).

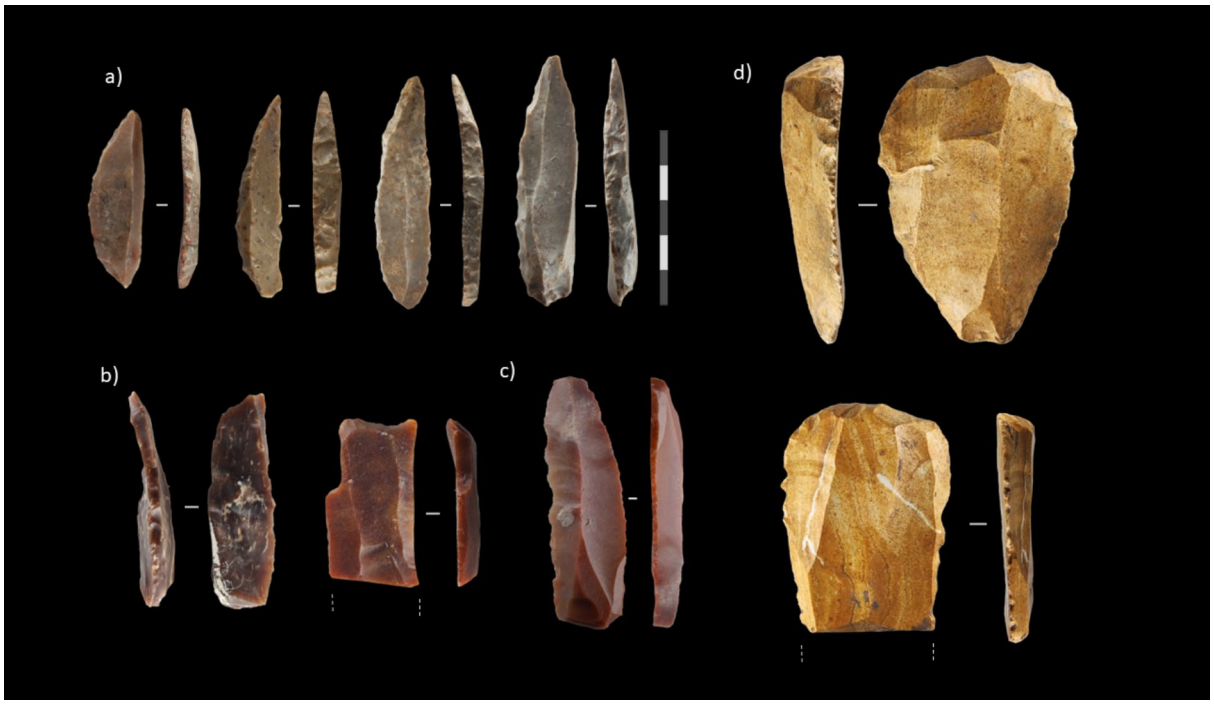


Fig. 6 Examples of retouched Châtelperronian tools. **a** Curved-backed points/knives (Châtelperronian points), **b** burins (dihedral and on truncation), **c** wide-fronted end-scrapers produced on large laminar rejuvenation flakes. Note the bipolar backing on A2-4. The burins (b) are single burins on truncations produced on laminar blanks. Artefacts are from the Châtelperronian of Quinçay (a, c) and Les Cottés (b)

Core Discard

A recurring and notable feature of discarded blade and bladelet cores in the Châtelperronian—which can in some sense in fact be considered quite typical of the industry—is a series of deep hinged removals affecting one or more of the flaking surfaces (Bordes & Bachellerie, 2018; Roussel et al., 2016). This may relate to the utilisation of a more internal striking gesture in the final phases of core exploitation—as may be evident in the pronounced *contra bulbs* visible in the negatives of final removals. This pattern has been interpreted as being related to apprenticeship in flintknapping (Bordes & Bachellerie, 2018).

Targeted Products and Retouched Tools

Châtelperronian blade core reduction is targeted near-exclusively at obtaining one product: regular blades for the manufacture of the arch-backed points which typify this industry (Fig. 6a). The targeted blanks are straight, sub-parallel blades predominantly between 35 and 85 mm in length, 12–35 mm in width, and 4–9 mm in thickness. Additionally, naturally backed blades detached are sought after for the production of Châtelperronian points.

Second-choice blades are frequently modified by a lateral retouch (marginal or abrupt), or converted into simple dihedral burins (Fig. 6b), while more robust blades and technical flakes detached from the wide flaking surface of cores are converted to end-scrapers (e.g. laminar rejuvenation flakes) (Fig. 6c). At some sites, the discrete production of elongated flakes has been identified—linked to the manufacture of large-fronted end-scrapers (Michel et al., 2019). The Châtelperronian toolkit consists near-exclusively of Upper Palaeolithic tool forms produced on products deriving from well-developed laminar core reduction methods (Fig. 6). Lamellar reduction seeks the production of relatively regular, sub-parallel bladelets—which are most often left unretouched. In some contexts, these unretouched lamellar products show evidence of use (Bodu et al., 2017). When retouch is present, oblique truncations—somewhat mirroring the retouch of Châtelperronian points—are present. In addition, direct or inverse lateral retouch on bladelets is observed at several sites—including Les Cottés, Quinçay, and Aranbaltza II (Bachellerie, 2011; Bodu et al., 2017; Discamps et al., 2019; Rios-Garaizar et al., 2022; Roussel, 2011; Roussel et al., 2016; Soressi et al., 2006; Talamo et al., 2012, 2020).

Summary and Reflection on the Position of the Châtelperronian Within the Broader Relevant Technological Landscape

Châtelperronian lithic technology reflects a well-developed laminar reduction system which is initiated and maintained through systematic cresting procedures (antero-lateral, postero-lateral). Two platforms are commonly opened, and blades are detached in alternating series. The idealised core reduction method can be considered a variant of 'asymmetric core reduction' (Roussel, 2011; Roussel et al., 2016; Zwyns, 2021). *Plein debitage* is most likely detached utilising a soft-stone percussor and more marginal percussion, while secondary products (technical flakes, debordant blades etc.) can show signs of a more internal percussion gesture and are often converted into end-scrapers or cores for small lamellar elements (bladelets). Arch-backed points (Châtelperronian points) are often the most numerous, and most distinctive, retouched element within Châtelperronian assemblages. Their size can vary widely, from near-bladelet-sized examples to robust and heavily backed examples. The rest of the retouched toolkit consists near-exclusively of 'Upper Palaeolithic' tool forms (end-scrapers, 'simple' dihedral burins, laterally retouched blades etc.). The production of bladelets in this industry, including rare retouched bladelets, has now been demonstrated at multiple sites and in multiple modalities.

Châtelperronian lithic technology is fully 'Upper Palaeolithic' and retains no 'Mousterian' reflections as are expressed—for example—in the European IUP (i.e. systematic internal hard-hammer percussion, platform faceting, and production of Levallois-type points). The 'transitional' label, when used to qualify the technology of this industry, is in fact a misnomer, and, as has been repeatedly highlighted, should be entirely abandoned. Somewhat ironically, it is in fact the Initial Upper Palaeolithic complex that could be considered technologically 'transitional'. Conversely, the Châtelperronian in fact seems to pre-empt behaviours which are subsequently further developed and consolidated within the Early Upper Palaeolithic (EUP) of western Europe, for example in the Protoaurignacian. Features that are characteristic of both the Châtelperronian and subsequent EUP industries—e.g. soft-stone marginal percussion, abraded platforms, fully laminar debitage, lack of convergent Levallois-type points—are effectively absent from any well-described assemblages attributed to both the European Middle Palaeolithic (MP) and IUP.

Some Prospects and Problems Concerning Châtelperronian Origins, Maker(s), and Implications

The above review confirms the Châtelperronian as a distinctive, coherent, blade-and-bladelet-based lithic industry of the fully Upper Palaeolithic-type. The Châtelperronian, unlike what is seen in the European IUP and late MP, is a stone tool industry which is near-exclusively aimed towards the systematic obtention and modification of regular blades and bladelets produced from well-developed laminar core technologies. Below, we discuss a number of prospects, problems and uncertainties facing existing perspectives on the origins, and maker(s) and implications of the Châtelperronian—taking into account technological, chronological, geographic, stratigraphic, and genetic perspectives.

An Intrusive Origin/Source for the Châtelperronian Resolves the Issue of Ambiguous Local Continuity

The traditional formulation for a local origin of the Châtelperronian has increasingly been pressured by stratigraphic, technological, and chronological inconsistencies. The elongated production partially characterising the 'MTA Type-B'—traditionally proposed as the cultural substrate of the Châtelperronian—is separated from the Châtelperronian by at least a Discoidal and likely also a Levallois phase at several sites where they occur together (Gravina & Discamps, 2015; Gravina et al., 2022; Jaubert, 2011; Jaubert et al., 2011). For example, at Le Moustier, the Châtelperronian is separated from the elongated production characterising the 'MTA Type-B' by several thousand years and almost 2 m of typical flake-based Discoidal and Levallois technologies (Gravina & Discamps, 2015). The issue of the abrupt and widespread appearance of a fully developed, volumetric, and crest-based blade and bladelet technology would be resolved by an intrusive model—releasing the Châtelperronian from increasingly ambiguous arguments for local technological continuity. The reality is that the appearance of the Châtelperronian marks, in large part, the total replacement of Mousterian technological sensibilities across the region. One notable exception to this pattern, however, is the unambiguous volumetric laminar debitage(s) reported from a number of sites in the Bergerac region thought to belong to MIS3—specifically those exhibiting bidirectional reduction patterns (see Ortega et al., 2022, for a detailed synthesis). These technologies indeed represent highly interesting datapoints, which are relevant to these discussions, and should be considered an important topic for future work.

From a higher-level viewpoint, there are a number of ways to interpret technological changes in the Palaeolithic record beyond the two most common approaches (local continuity and geographically continuous migration). For example, a migration can be geographically discontinuous—i.e. 'invisible' between the nodes—due to maritime voyages. Alternatively, a small and highly mobile migrating population may not leave a lithic footprint dense enough to be recognised as a discrete industry between the areas and/or sites which they occupied more intensely and for a longer

duration. For example, we can consider the recently published Micoquian expression at Chagyrskaya Cave in the Altai foothills—roughly 3000 km away from the suggested geographic distribution of this industry (Kolobova et al., 2020). This appears to be an example of a long-distance population movement associated with a discrete lithic toolkit—which is in fact supported by genetic evidence (*ibid.*). It may be a poignant reminder that the movement of highly mobile hunter-gatherer groups can remain archaeologically invisible between the central nodes—and that a large geographic distance between similar archaeological assemblages does not necessarily preclude a direct connection/relationship between those assemblages. And, conversely, a similar geographic distribution between two sets of assemblages is not necessarily evidence for a connection (Gravina & Discamps, 2015).

The LRJ and Uluzzian have no Obvious Techno-cultural 'Sources' and are Presently Associated Exclusively with *Homo sapiens* Fossil Remains

Relevant to discussions concerning the origins of the Châtelperronian is the fact that other sub-contemporaneous industries in Europe similarly show no obvious sources. This is perhaps particularly the case for the Uluzzian industry of Italy, but also the northern European Lincombian-Ranisian-Jerzmanowician (LRJ)—which has recently been associated with multiple individuals presenting *Homo sapiens* mtDNA at the key site of Ranis, Germany (Mylopotamitaki et al., 2024). However, and interestingly, an argument has recently been made that LRJ technology may have derived from Bohunician industrial roots—potentially representing a 'Late Initial Upper Palaeolithic' entity (Demidenko & Škrdla, 2023). Concerning the Uluzzian, this industry represents an equally pronounced technological rupture with the regional Mousterian as the Châtelperronian, but follows a divergent trajectory with no known analogues in Eurasia—characterised predominantly by the proliferation of bipolar-on-anvil knapping (Rossini et al., 2022). The LRJ represents an interesting example as, similarly to the Châtelperronian, it is from a technological perspective characterised by the production of blades from bidirectional cores utilising marginal, soft-stone percussion (Demidenko & Škrdla, 2023; Flas, 2011). Bladelet production has also been documented at some LRJ sites (Demidenko & Škrdla, 2023), and some cores (both blade and bladelet) show intriguing structural similarities to Châtelperronian counterparts (see for example Fig. 5 in Flas, 2011). Typological differences are pronounced however—with the LRJ typified by the production of large points characterised by flat, invasive retouch on one or both surfaces (Demidenko & Škrdla, 2023; Flas, 2011; Wiśniewski et al., 2022). Nonetheless, in terms of blade production, an argument could be made that—from a European perspective—the LRJ and Châtelperronian may share the most similarities of any co-eval industries during the MP-UP transition. To what effect, if any at all, this similarity may be indicative of some form of deeper connection is beyond the scope of this paper—but it strikes us as a curious and as of yet unexplored comparison.

An East-to-West Movement Pattern of Initial and Early Upper Palaeolithic Technologies is not Self-evident in the Available Chronological Data—which may Lend Support to Alternative Movement/Migration Scenarios

The spread of Initial and Early Upper Palaeolithic technologies across Europe is most commonly considered to have followed an east-to-west pattern, mirroring the assumed movement routes of *Homo sapiens* during this period. However, despite the increasing collection of high-quality chronological data, such a pattern is not strictly visible. This is not to say that such a model is therefore false, but simply that it is not demonstrably clear with the currently available data. For example, if we accept the Neronian as an expression of the Initial Upper Palaeolithic, the IUP at Grotte Mandrin and the Protoaurignacian at sites such as Isturitz and Gatzarria currently represent the earliest directly dated occurrences of these respective technologies in any region of Europe (Barshay-Szmidt et al., 2012, 2018, 2020; Djakovic et al., 2022; Slimak et al., 2022). Furthermore, both the Bohunician IUP complex of Moravia (Petřík et al., 2022) and the LRJ at Ranis (Mylopotamitaki et al., 2024) appear to pre-date the IUP at eastern sites such as Bacho Kiro (Bulgaria) (Fewlass et al., 2020). Given these emerging patterns, it is not self-evident that a straightforward east-to-west movement is the best fit for the appearance and spread of Initial and Early Upper Palaeolithic technologies during the Middle to Upper Palaeolithic transition in Europe—which may lend support to alternative migration and/or development scenarios (e.g. Slimak, 2023). In fact, it should be noted that the available genetic data on some of the earliest *Homo sapiens* in Europe seem to indicate that we are likely dealing with small, unrelated groups arriving independently in different regions—rather than reflecting anything resembling a uniform wave of settlement (e.g. Hajdinjak et al., 2021; Mylopotamitaki et al., 2024; Prüfer et al., 2021).

Both Neandertal and *Homo sapiens* Fossil Remains are Now Reported in Association with Châtelperronian Artefacts at Grotte du Renne, Arcy-sur-Cure (France)

The paleoanthropological evidence from the Châtelperronian levels at Grotte du Renne, Arcy-sur-cure, has recently been expanded via the identification of an immature *Homo sapiens* pelvic fragment in association with the suite of

Neandertal skeletal remains (Bailey & Hublin, 2006; Hublin et al., 1996). This, for the moment, represents both the first evidence of an association between *Homo sapiens* and the Châtelperronian and the only example of the co-occurrence of Neandertal and *Homo sapiens* fossil remains in the same archaeological context in any region of Europe. However, given the potential issues concerning the integrity of the Châtelperronian assemblages at Grotte du Renne (see Teyssandier, 2024, for a detailed exposition), the unilateral attribution of the human remains to the Châtelperronian should at present be taken with caution. The human remains were excavated from the Grotte du Renne during the 1950s, and no recent taphonomic or spatial evaluation of the sequence have been conducted. While the potential importance of this co-occurrence cannot be understated, as it stands the uncertain reliability of these associations precludes any strong conclusions. However, it is important to emphasise that the direct-dating of a genetically identified Neanderthal bone from the Grotte du Renne is consistent with the time-window identified for the formation of Châtelperronian assemblages (see Djakovic et al., 2022, for a review). While this does not itself demonstrate the reliability of the fossil-artefact association, it must be taken into account—and may minimally indicate that, irrespective of the authors of the industry, Neandertals were present in the region during this time window *(ibid.)*.

Châtelperronian Laminar Technology is More 'Upper Palaeolithic' than 'Initial Upper Palaeolithic', and Retains no Mousterian Tendencies

Given the recent proliferation of work on the Initial Upper Palaeolithic complex, and its presently unilateral association with *Homo sapiens* remains, it is important to stress here again that—from a technological perspective—the Châtelperronian does not represent an Initial Upper Palaeolithic expression. The production of blades and Levallois-type points from a non-Levallois reduction sequence utilising hard-hammer percussion and platform faceting, which can effectively be considered the single unifying feature of the IUP across its geographic distribution (e.g. see Kuhn & Zwyns, 2014), is a behavior which is entirely absent in the Châtelperronian. Instead, the Châtelperronian in fact shares substantial technological tendencies with subsequent Upper Palaeolithic industries—namely an explicit focus on the production of regular blades and bladelets utilising a marginal percussion gesture and/or soft-stone percussor. It appears to be representative of a package of behaviors which become increasingly dominant across Europe following the disappearance of Initial Upper Palaeolithic technologies.

Technological Similarities Between the Châtelperronian and the Regional Protoaurignacian are Becoming More Pronounced, and Require Consideration

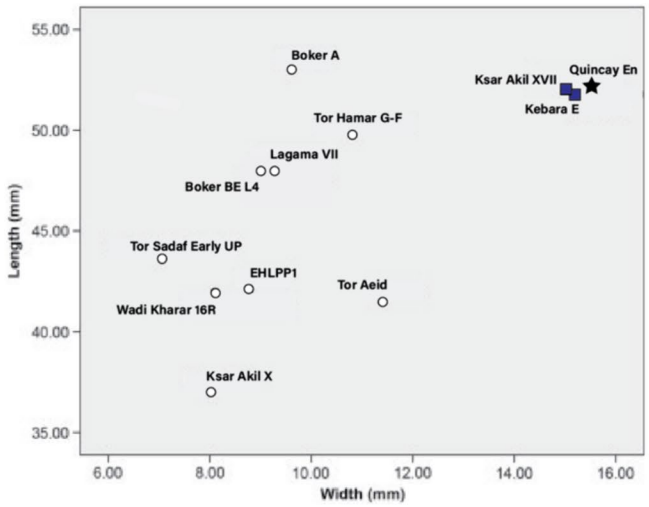
Some recently excavated Châtelperronian assemblages—in particular Aranbaltza II—show a pronounced and well-developed bladelet component (Rios-Garaizar et al., 2022) featuring both technological and typological (Dufour bladelet) affinities with the regional Protoaurignacian. While the underlying reason for these similarities remains unclear, it is notable that in terms of local continuity, the regional Protoaurignacian appears to show substantially more continuity with the Châtelperronian than the Châtelperronian does with the preceding Mousterian (Bordes & Teyssandier, 2011; Teyssandier, 2024). A shared cultural substrate for these industries is one mechanism for explaining this pattern (Slimak, 2023), but so too is the partial contemporaneity and interaction of the groups responsible for producing these assemblages (Djakovic et al., 2022; Roussel et al., 2016)—irrespective of the biological classification of their respective makers. In either case, in terms of regional technological continuity and its potential implications, shifting the focus from the Mousterian-Châtelperronian interface to the Châtelperronian-Protoaurignacian interface may be a productive re-orientation.

An Industry with the Same Set of Typo-technological Features as those that Characterise the Châtelperronian Does Not Appear to have Been Produced, in the Current State of Knowledge, by Any Other Neandertal Groups

This statement has nothing to do with discussions of cognitive capacity or behavioral modernity, but simply serves to highlight the fact that the set of features which characterise the Châtelperronian appear to be a pronounced outlier when compared to all other industries presently associated with Neandertals across their temporal and geographic distribution. Of course, this pattern is largely a construction of research history—and could very well be rendered incorrect or irrelevant with new discoveries and re-evaluations. Nonetheless, the point remains that as it stands, there exists no clear typo-technological analogue to the Châtelperronian in the broader Neandertal techno-cultural repertoire—and the potential importance of this observation, or lack thereof, must remain a topic of consideration.

There Appears to be Clear Typological and Technological Similarities Between the Châtelperronian and Northern Early Ahmarian Stone Tool Industries Despite their Geographic Distance

The morpho-typological similarities between the retouched backed points of the Northern Early Ahmarian



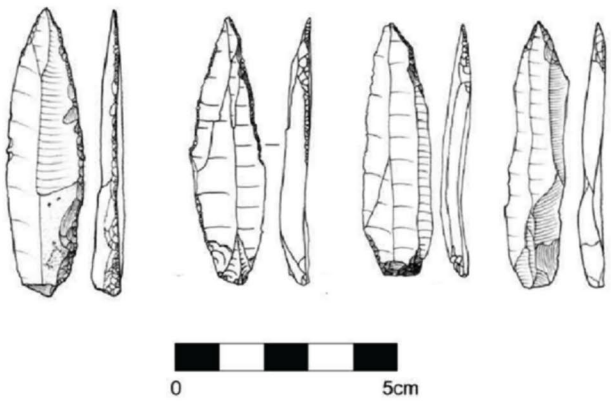


Fig. 7 Left: scatterplot showing mean length and width of points from the Southern Early Ahmarian (white circles), Northern Early Ahmarian (dark squares), and Châtelperronian of Quinçay (black star) (modified with permission after Kadowaki et al., 2015). Kebara E ($n=78$), Ksar Akil XVII ($n=78$), Quincay En ($n=77$). Right: Example of Ahmarian retouched points from Üçağızli cave (modified with permission after Kuhn et al., 2009)

and the Châtelperronian are notable (Slimak, 2023)—particularly when considering that the mean size (length and width) of backed points from Ksar Akil (layer XVII, $n=75$) (Bergman, 1981) and Kebara (layer E, $n=78$) (Ziffer, 1978) form a tight cluster with that of the Châtelperronian points recovered from Quinçay (layer En, $n=77$) (Roussel et al., 2016) (Fig. 7) when compared to those of the Southern Early Ahmarian complex—which are instead produced on bladelets (Kadowaki et al., 2015). The reported technological similarities between these industries are also pronounced (see Slimak, 2023, and Supplementary Information for a detailed exposition) and, considering their potential contemporaneity, are either a strikingly poignant example of lithic typo-technological convergence or, indeed, indicative of some form of more explicit connection. Their shared use of bidirectional exploitation, focus on blade production, and subsequent conversion of these elements into arch-backed points (e.g. see Slimak, 2023) clearly distinguish them—from a typo-technological perspective—from industries such as the Protoaurignacian and Southern Early Ahmarian (e.g. see Gennai et al., 2021). However, short of any supporting evidence, without an extensive demonstration that these assemblages are effectively identical beyond a reasonable doubt, a connection remains fascinating but requires further in-depth evaluation. Nonetheless, and irrespective of the mechanism, the pronounced similarity between the trajectory of technological changes observed at opposing ends of the Mediterranean Sea between ~ 55 and 40 kya cal BP (Slimak, 2023) is an observation which requires open-minded consideration.

There is no Evidence of Sea-faring During the Middle to Upper Palaeolithic Transition, which Casts Important Doubt on a Direct Connection Between the Levant and Western Europe

There exists in this period no physical evidence of sea-faring craft or related technology of any kind, and in any region. However, there is indirect evidence of sea-faring based on the arrival of *Homo sapiens* to Australia ~ 65 kya cal BP (Clarkson et al., 2017)—and complicating these matters is the fact the sea level rises have likely inundated many archaeological sites which are relevant to these discussions. Given the timing of the peopling of Australia, it is not unreasonable to speculate that some human groups were capable of seafaring during the MP-UP transition (~ 55–40 kya cal BP) (Slimak, 2023). Modelling has shown that the accidental arrival of humans to Australia from the islands of Timor and Roti by drifting alone is very unlikely to have occurred (Bird et al., 2018), while genetic evidence indicates that Australia was colonised in a single phase—with very limited geneflow following this colonisation—suggesting a founding population large enough to sustain long-term survival (Tobler et al., 2017). With this said, there are a number of important issues underlying the sea-faring hypothesis for a connection between the Levant and western Europe during the Middle to Upper Palaeolithic transition which require consideration. Western Europe, unlike Australia, does not require a sea crossing for colonisation—and it remains challenging to explain how populations embarking on a crossing from the Levant to western Europe would effectively avoid Cyprus, the Aegean Islands, Greece, Sicily, the Balearic Islands,

Sardinia, and Corsica. It is reasonable to expect that populations which colonised islands, and were well adapted to such environments, were more likely to have mastered seafaring compared to Levantine IUP/EUP populations—that appear to show no evidence of potentially related behaviors such as pelagic fishing. Of course, given the fragmented character of the archaeological record, the absence of evidence is not necessarily evidence of absence—but these discrepancies cannot be overlooked.

Some Potential Paths Forward

ZooMs, sedDNA, and Recovering DNA from Bone Tools and Personal Ornaments

The recovery of sedimentary DNA from bulk sediment and indurated blocks (Massilani et al., 2022), in combination with ZooMs analysis of non-identifiable faunal fragments from Châtelperronian contexts, will undoubtedly continue to progress discussions concerning the makers and origins of this industry in the years to come. Additionally, the recent publication by one of us and collaborators of a method for the non-destructive extraction of ancient human DNA directly from Palaeolithic ornaments and tools made of bone or tooth opens a new door towards connecting discrete hominin individuals with discrete archaeological artefacts (Essel et al., 2023). Given the emerging picture of demographic complexity in this period (e.g. Hublin et al., 2020; Hajdinjak et al., 2021; Prüfer et al., 2021; Vallini et al., 2022; Slimak et al., 2022), it is likely also necessary to entertain the hypothesis of mixed groups (Compton et al., 2021; Stringer & Crété, 2022). However, it is critical that taphonomic approaches be implemented to assess the integrity of archaeological contexts (Bordes, 2003; Gravina et al., 2018; Texier, 2000; Villa & Soressi, 2000) prior to the construction of higher level models and sedDNA analysis.

Chronology, Contemporaneity, and the Laschamp Geomagnetic Excursion

Producing precise and accurate absolute chronologies for the Middle to Upper Palaeolithic transition is full of hurdles, but there has been tremendous progress in overcoming many of the inherent limitations (e.g. Higham et al., 2006; Jacobs et al., 2015; Bard et al., 2020; Heaton et al., 2020; Devièse et al., 2021). To complement radiocarbon and OSL chronologies, an as of yet largely untapped resource—to our knowledge—may be the integration of paleomagnetic analyses in establishing relative chronologies and measures of contemporaneity between archaeological assemblages (Bard et al., 2020; Heaton et al., 2020; Sier et al., 2013). Specifically, the Laschamp geomagnetic excursion can be detected in geological layers deposited in the period of time roughly 43–41 thousand years ago (Bourne et al., 2012). This is precisely the critical period for the Châtelperronian and Protoaurignacian in France and northern Spain, and shortly precedes the disappearance of Neandertals from the fossil record based on radiocarbon estimates (Devièse et al., 2021; Djakovic et al., 2022; Higham et al., 2014). Considering the large probability ranges inherent to radiocarbon dating at this timeframe (~55 to 40 kya cal BP), the Laschamp could prove a useful tool to establish a higher resolution measure of contemporaneity between stratigraphic layers in this region (and beyond)—potentially both inter- and intra-industry.

As an example, the identification of the Laschamp event in stratigraphic layers preserving both Châtelperronian and Protoaurignacian occupations (at different sites/regions) may lend strong empirical credence (or lack thereof) to the idea that these occupations were partly contemporaneous (e.g. Djakovic et al., 2022). In theory, given the chronologies presently established through absolute dating methods, the Laschamp geomagnetic excursion could have taken place during either the final Mousterian, Châtelperronian, Protoaurignacian, or a combination of the three. Furthermore, it is possible that the application of such research to Levantine sequences—where C14 suffers from noted preservation issues—may too prove a fruitful endeavour. For example, towards disentangling the chronologies of the Northern and Southern Early Ahmarian, the former of which has been suggested to potentially precede the latter chronologically (e.g. Kadowaki et al., 2015).

Returning to Key Sites and Sequences

The re-evaluation of key sites and sequences will continue to be a crucial path towards a better understanding of the Middle to Upper Palaeolithic transition in this region. One need only look at the results of recent work at a number of eponymous MP-UP sites in France to understand the value in critical re-evaluations and renewed sampling of sequences central to higher level interpretative models (Bordes, 2003; Faivre et al., 2017; Gravina & Discamps, 2015; Gravina et al., 2018; Jaubert et al., 2011; Rendu et al., 2019; Soressi et al., 2013). In this vein, a suite of multidisciplinary work is currently in progress at the site of Quinçay (France)—a site with a pronounced bladelet component (Roussel et al., 2016) and one of two Châtelperronian sites from which personal ornaments have been published (Roussel et al., 2016; Soressi & Roussel, 2014; Welker et al., 2017). Interpretations of the Middle to Upper Palaeolithic transition based on sites excavated many decades ago should be—in general—treated with caution and more attention should be paid to recently excavated sites. This is particularly the case when constructing reliable interpretations pertaining to technological

characteristics and, perhaps especially, fossil and/or sedDNA associations.

Conclusions

This review has resulted in more questions than answers, which in some sense mirrors the evolution of perspectives on the Châtelperronian over the last three decades of research. As it stands, the makers and origins of the Châtelperronian remain a difficult dilemma to unravel—a difficulty that is at least partly due to the still-limited paleoanthropological record for this industry (despite being one of the most abundant for the time period), uncertainties in the reliability of relevant hominin associations, and an enforced reliance on technological data for the construction of higher-level explanatory models. It appears that the consensus which exists today is that this industry represents a discrete, coherent, and relatively short-lived—based on the relatively ephemeral nature of most Châtelperronian deposits—series of occupations which may signify some form of population turn-over following the final Mousterian in the region. This is tentatively and indirectly supported by the identification of a *Homo sapiens* neonate within the Châtelperronian levels at Grotte du Renne, and also the pronounced techno-cultural rupture characterising the transition from the late Mousterian to the Châtelperronian across its geographic distribution. This is made particularly poignant when considering the fact that, across Europe, *Homo sapiens* remains are now identified in various archaeological contexts pre-dating 40 kya cal BP (including in France)—either co-eval with or pre-dating the onset of the Châtelperronian in western Europe. On top of this, some of these individuals show evidence of a recent Neandertal ancestor—possibly suggesting mixed groups within Europe—while, curiously, not a single late Neandertal individual has yet exhibited evidence of a *Homo sapiens* ancestor. While these observations do not in themselves necessarily have a direct bearing on the Châtelperronian, they create a substantial transformation of the context in which the Châtelperronian needs to be situated.

The logical consequence of this transformation is the realisation that existing explanatory models for the emergence of this industry are likely, in large part, no longer relevant. What must inevitably follow is the formulation, testing, and open-minded consideration of hypotheses which may better explain the paleoanthropological, genetic, and archaeological data. The reality is that not only does the Châtelperronian appear to represent an intrusive techno-cultural entity in the regional record, but it also has no near-equivalents in the broader Neandertal record. While the identification of an explicit cultural substrate or 'source' for this industry may simply be unattainable, the increasing acceptance of the Châtelperronian as an intrusive entity underpinned by some form of demographic transformation warrants such an exploration—the results of which should not be discarded without critical consideration. In more general terms, the higher-level research agenda for this industry is clearly transitioning from one in which data is used to strengthen pre-existing models into one which prioritises the testing of emergent hypotheses which are more consistent with the state of the art. As an example, it is questionable whether a Neandertal-Châtelperronian association is relevant to discussions concerning a local origin of this industry. The relationship between a Neandertal association and a local technological origin is a non-sequitur—i.e. the conclusion does not logically follow the preceding statement—and these observations should instead be conceptualised as independent variables. Put another way, a Neandertal-Châtelperronian association does not necessarily imply a local origin—especially when considering indication of a potential population turnover in Europe towards the end of Neandertal history (Hajdinjak et al., 2018).

The Châtelperronian is a fully Upper Palaeolithic techno-cultural entity which appears to be contemporaneous with the disappearance of morphological Neandertals from the fossil record. Acknowledging important questions concerning integrity, both Neandertal and *Homo sapiens* remains are now reported from the key site of Grotte du Renne and the Châtelperronian is, more broadly, situated in a period in which both Neandertals and *Homo sapiens* co-existed in the broader European landscape. This complex situation places increasing importance on modern excavations and re-appraisals. Of course, it is reasonable to expect that archaeological assemblages produced by mixed groups are a feature of this record. A local origin of this industry should no longer be considered the dominant model, and some form of population replacement/transformation featuring the introduction of novel technological behaviours and total replacement of pre-existing behaviours needs to now be examined in depth. The character of Châtelperronian lithic technology has no analogues in the broader Neandertal record, and is more consistent with what is known for *Homo sapiens* populations both within Europe and beyond. The search for an external 'source' for the Châtelperronian may be fruitless, but hypotheses should be evaluated with consideration. From our perspective, it is with the cautious acceptance of these postulates that a re-conceptualisation of the origins and implications of the Châtelperronian will flourish in the years to come.

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Declarations

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