At the end of the \(^{14}C\) time scale—the Middle to Upper Paleolithic record of western Eurasia

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Abstract

The dynamics of change underlying the demographic processes that led to the replacement of Neandertals by Anatomically Modern Humans (AMH) and the emergence of what are recognized as Upper Paleolithic technologies and behavior can only be understood with reference to the underlying chronological framework. This paper examines the European chronometric (mainly radiocarbon-based) record for the period between ca. 40 and 30 ka \(^{14}C\) BP and proposes a relatively rapid transition within some 2,500 years. This can be summarized in the following falsifiable hypotheses: (1) final Middle Paleolithic (FMP) “transitional” industries (Uluzzian, Chatelperronian, leaf-point industries) were made by Neandertals and date predominantly to between ca. 41 and 38 ka \(^{14}C\) BP, but not younger than 35/34 ka \(^{14}C\) BP; (2) initial (IUP) and early (EUP) Upper Paleolithic “transitional” industries (Bachokirian, Bohunician, Protoaurignacian, Kostenki 14) will date to between ca. 39/38 and 35 ka \(^{14}C\) BP and document the appearance of AMH in Europe; (3) the earliest Aurignacian (I) appears throughout Europe quasi simultaneously at ca. 35 ka \(^{14}C\) BP. The earliest appearance of figurative art is documented only for a later phase ca. 33.0/32.5–29.2 ka \(^{14}C\) BP. Taken together, the Middle to Upper Paleolithic transition appears to be a cumulative process involving the acquisition of different elements of “behavioral modernity” through several “stages of innovation.”

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Introduction

The replacement of Neandertals by Anatomically Modern Humans (AMH) and the change from the Middle to the Upper Paleolithic in western Eurasia mark crucial developments in human biological and cultural history and are among the most debated issues in paleoanthropology and archaeology. The frequently heated discussion by specialists in many fields is often dominated by the assumption that the two topics are synchronous and causally linked. Hypotheses range from the idea that behavior is clearly species-related (e.g., Lahr and Foley, 1998), implying that replacement of Middle Paleolithic technologies by Upper Paleolithic ones was an intrusive and “revolutionary” process that spread relatively rapidly from a specific core area (e.g., Bar-Yosef, 1998; cf. Bar-Yosef, 2001), to the proposal that the observed cultural changes are trans-specific, with aspects of Upper Paleolithic technology being invented independently by Neandertals and AMH (Zilhão and d’Errico, 1999; d’Errico, 2003; Zilhão, 2006a) and/or adopted by the former following contact with the latter (e.g., Hublin et al., 1996; Mellars, 2000).

In both the anthropological and the archaeological discussion it is clear that meaningful models can only be created within a reliable chronological framework defined by highly accurate stratigraphic records and chronometric age estimates. However, it is increasingly clear that the database for constructing a chronology for the period under consideration (ca. 40–30 ka \(^{14}C\) BP) is flawed, and that major contextual and methodological problems have been underestimated (cf. Blockley et al., 2008). This paper discusses critically the available chronometric records, taking into account recent advances in radiocarbon dating and interpretation, and addresses their implications for specific problems in both the physical anthropological and cultural records.

Scenario

The hypothesis that all modern humans ultimately descend from a small population of African origin is consistently supported by the analysis of both recent human mitochondrial and nuclear DNA (Forster, 2004) and also by the early ages established for early African and Near Eastern AMH (White et al., 2003; Grün et al., 2005; McDougall et al., 2005; Trinkaus, 2005). Near Eastern data suggest a northward expansion of early AMH as early as 135–100,000 years ago (Grün et al., 2005; cf. Shen and Michel, 2007), in what was apparently only a temporary incursion into Eurasia since...
younger hominin fossils from Amud, Kebara, and Dederiyeh (e.g., Akazawa et al., 1998; Hovers, 2006) are Neandertals of western Eurasian origin (cf. Fig. 1). Based on studies of fossil mtDNA it has been argued that Neandertals made no recognizable contribution to the gene pool of modern Homo sapiens, suggestive of a rapid replacement scenario (Serre et al., 2004; Excoffier, 2006), although recently, limited genetic transfer between the two lineages has been suggested as a possible scenario (cf. Eswaran et al., 2005; Green et al., 2006).

It has been suggested that certain morphological features of Neandertal and ancient AMH skeletons provide evidence for at least some intermixture of the two hominin types (Rougier et al., 2007), an interpretation contradicted by the most recent morphological analysis of the early AMH calvaria from Cioclovina, Romania, which emphasizes their entirely modern character (Harvati et al., 2007). Should, however, the first scenario be accepted, the absence of genetic evidence for admixture would imply that there was a subsequent loss of overall genetic diversity in the surviving present day human population (Zilhão, 2006a: 8).

For any discussion of Neandertal extinction and their potential merging with AMH (Fig. 1), the timing and duration of possible contact between them are of critical importance. A brief period of interaction would suggest practically instantaneous replacement of Neandertals by AMH (Currat and Excoffier, 2004), whereas coexistence over several thousands of years would imply only a gradual diffusion of AMH into Eurasia (Zilhão, 2006b). For the latter scenario it has been stated that AMH moved into Europe from the East (Bar-Yosef, 2001; Bolus and Conard, 2001; Conard and Bolus, 2003; Mellars, 2004, 2006a,b), possibly across a broad front (e.g., Bocquet-Appel and Demars, 2000), or by penetration along specific axes such as the major river systems of the Danube (Conard and Bolus, 2003) and the Don (Anikovich et al., 2007: 225). For many authors these movements seem to be mirrored in the spatio-temporal patterns of the Aurignacian, which is occasionally associated with early AMH (Churchill and Smith, 2000; Paunescu, 2001; Trinkaus et al., 2003; Bailey and Hublin, 2005; Trinkaus, 2005; Wild et al., 2005).

Given the great geographical extent of Europe it seems plausible that the last Neandertals may have been contemporaries of European early AMH, and repeated claims have been made for late Neandertal survival in refugial situations most distant to early AMH penetration into the continent (Zilhão, 2006b). In similar form, Neandertal refugial survival has been suggested for the southern European peninsulas of Iberia (e.g., Vega Toscanó, 1990, 1993; Zilhão, 1993, 2000, 2006b), Italy (Kuhn and Bietti, 2000), the Crimea (Marks and Monigal, 2000), and for the Caucasus region (Bar-Yosef et al., 2006). Most recently, radiocarbon dates from Gorham’s Cave on Gibraltar have led Finlayson et al. (2006) to propose survival of the Middle Paleolithic and—implicitly—of the last Neandertals at the southern tip of the Iberian Peninsula until as recently as 28 ka, and probably even 24 ka 14C BP, although context and relevance of the dated samples for the age of the Middle Paleolithic levels at Gorham’s Cave were immediately questioned (Zilhão and Pettitt, 2006). A large proportion of the radiocarbon data available for the southern Iberian Middle Paleolithic is of poor quality, with measurements often obtained several decades ago and/or displaying high standard deviations; frequently, they are contradicted by results obtained by other dating methods (e.g., Zafarraya: Hublin et al., 1995) and they often derive from poorly recorded contexts (Joris et al., 2003; cf. Vaquero et al., 2006).

As is exemplified in this discussion, our perception of the relationship between Neandertals and early AMH reflects the course of European Paleolithic research, which led to the recognition of two distinct monolithic blocks, the Middle and the Upper Paleolithic, believed to be essentially different and implicitly associated with the two hominin types. Stratigraphic observations and improved absolute dating methods, in combination with detailed techno-typological studies, today show that change from the Middle to the Upper Paleolithic in western Eurasia was far more complex in both time and space than could be expressed by simple models of replacement.

It is now generally recognized that the late Middle Paleolithic (LMP) is quite heterogeneous, comprising diverse and regionally different assemblages, which can be defined as distinct
spatio-chronological entities such as the western European Mousterian of Acheulian tradition (MTA; Soressi, 2002), the Central European Keilmessergruppen (Bosinski, 1967; Jöris, 2004), or the Eastern European Micoquian and various other industries on the Crimean Peninsula, Russian Plain, and Caucasus (e.g., Chabai, 2003; Sinitsyn, 2003; Monigal, 2006; Usik et al., 2006). From all these cultural contexts, only Neandertal skeletal remains are known.

Beyond this, there exist "transitional" assemblage types that postdate the LMP but fall stratigraphically and chronometrically before the Aurignacian (Fig. 2a, b), and which are characterized by elements often regarded as reflecting "behavioral modernity," such as the systematic production of blades and higher frequencies of "progressive" or "Upper Paleolithic" lithic tool types, such as end-scrapers, burins, or backed pieces (cf. e.g., Bar-Yosef and Zilhão, 2006). Although there is no consensus on the defining criteria for this group (cf. Bar-Yosef, 2006a), use of the term "transitional industries" is often steered by an evolutionist concept of cultural change, with the implication that these assemblages represent some form of developmental stage between the Middle and the Upper Paleolithic. An alternate interpretation of the term regards

Fig. 2. a. European "transitional" industries. Map based on SRTM data; sea level lowered by 75 m. IUP = initial Upper Paleolithic; EUP = early Upper Paleolithic; the broken line divides the FMP "transitional" industries of northern Europe (leaf-point assemblages) from those of southern Europe (Chatelperronian, Uluzzian, Klasies). b. Earliest radiocarbon dated evidence for European Aurignacian industries. Map based on SRTM data; sea level lowered by 75 m.
these industries as “transitional” only because they fall chronologically between preceding unambiguous Middle and subsequent unambiguous Upper Paleolithic assemblages. Between these perspectives is room for a broad spectrum of views, which are often fundamentally influenced by a preference for either “cultural continuity” or “cultural hiatus.”

The appearance of innovative features within the “transitional” industries has been discussed as particularly relevant for the emergence of “behavioral” (or even cognitive, cf. d’Errico, 2003) modernity, for the question of respective Neandertal and AMH abilities and their potential interactions and for the origins of the Aurignacian. Among the major innovations commonly seen as milestones in the emergence of “modern” human behavior are the first appearance of personal ornaments; the emergence of a standardized bone, antler, and ivory weapon technology; and the earliest undeniable evidence for figurative art.

The earliest appearance of personal ornaments in association with specific pre-Aurignacian contexts has repeatedly provoked controversial discussion (for recent reviews see Alvarez Fernandez, 2006; Zilhão, 2007). If personal ornament is regarded as the prerogative of AMH, its presence in “transitional” contexts apparently associated with Neandertals, such as the Chatelperronian and related complexes with curved-backed pieces, requires explanation. A number of researchers interpret the presence of personal ornaments as due to contamination from younger, AMH-associated deposits (e.g., White, 2001). An opposed interpretation sees the presence of ornaments in “transitional” contexts as evidence for an independent evolution of “behavioral modernity” among indigenous Neandertals (d’Errico et al., 1998; d’Errico, 2003). An intermediate viewpoint accepts that Neandertals possessed personal ornaments but only acquired the cognitive skills implicit in their use as a result of acculturation following contact with intrusive AMH populations (e.g., Hublin et al., 1996; Mellars, 2000). In fact, the evidence for personal ornaments in “transitional” contexts attributed to Neandertals is generally quite limited.

By contrast, personal ornaments in the form of shell beads and, more rarely, animal teeth are regularly described from slightly younger Protoaurignacian “transitional industries” around the Northern Mediterranean (for recent reviews see Kozlowski, 1982; Kuhn and Stiner, 1998; Alvarez Fernandez, 2006; Vanhaeren and d’Errico, 2006; Zilhão, 2007; Joris et al., in press). Evidence of similar age comes from the southern Russian site of Kostenki 14 (Markina Gora) on the Don River, where a double-perforated marine shell (Columella sp.), apparently “…derived from a source no closer than the Black Sea…” (more than 500 km distant), was found in a pre-Aurignacian context (Anikovich et al., 2007: 225). That the occurrence of marine shell personal ornaments does not simply reflect proximity to the sea is also demonstrated by their considerable presence at the Protoaurignacian site of Grotta di Fumane (Bro glo and Gurioli, 2004; Broglio and Dalmeri, 2005), even today 200 km from the Ligurian coast and at that time still more distant from the low-sea-level Adriatic coastline.

Bone artifacts associated with “transitional” contexts, such as the Chatelperronian of Grotte du Renne (e.g., d’Errico et al., 2003) or Kostenki 14, level Ivb (Sintysyn, 2003), largely comprise whitened down bone awls with often rudimentary modification. They seem less a proof of “behavioral modernity” than continuation of the methods used since the Lower and Middle Paleolithic to produce wooden or bone artifacts (e.g., Thieme, 1997; Gaudzinski, 1999). This is in contrast to standardized Aurignacian projectile points of bone, antler, or ivory (cf. Albrecht et al., 1972) that are the result of a complex chain of production (cf. Lloïos, 2006).

The most conclusive evidence for the appearance of “fully” developed modern human behavior or cognition in the western Eurasian Paleolithic is provided by figurative art in the form of carved figurines, painted images, and picked engravings, first securely documented from Aurignacian contexts (Floss and Rouquerol, 2007; cf. Zilhão, 2007).

**Radiocarbon dating at the limits of the 14C-scale—problems and perspectives**

For a better understanding of the Middle to Upper Paleolithic transition and the last Neandertals/first AMH it is necessary to examine their absolute and relative chronological relationship at the highest possible level of accuracy. However, before the themes outlined above can be discussed with regard to their chronology, some methodological questions pertinent to radiometric dating must be addressed.

Together with reliable stratigraphic controls, radiocarbon dating provides the backbone for current anthropological and archaeological models, due to both its wide applicability and its high analytical precision. Other radiometric evidence is still applied quite unsystematically (but cf. Richter et al., 2008), and many methods have only limited suitability for the dating of archaeological or paleoanthropological samples and/or are of only relatively poor precision due to their large inherent standard deviations. On the other hand, the interpretation or assessment of radiocarbon dating results is greatly influenced by factors such as the choice of material sampled, the context of the sample within the site, and the pretreatment process applied to the sample (Joris et al., in press). The fact that the Middle to Upper Paleolithic transition and the replacement of the last Neandertals by early AMH lie close to the limit of the dating method leads to greater impression expressed as increasingly high standard deviations or infinite measurements.

The choice of sample is among the most important parameters for the measurement of radiocarbon ages, and their meaningful interpretation can only be based on rigorous procedures and protocols (e.g., Lowe and Walker, 2000; Pettitt et al., 2003). The specific location of a sample within a site can influence the interpretation of radiocarbon results and lead to discrepant age series within closely-related site contexts. Bones from Middle Paleolithic horizons inside the southern German Sesselfelsgruppe rockshelter produced radiocarbon ages in stratigraphical order, whereas samples from equivalent strata outside the rockshelter drip line gave significantly younger ages (Richter, 2004). The different methods applied in sample pre-treatment and removal of contaminants also directly influence results, and thus, the comparability of the different laboratories. For example, dates produced quite recently for the Upper Paleolithic burials of Sun’gir by different laboratories (Oxford: Pettitt and Bader, 2000; Arizona: Kuzmin et al., 2004) differ by several thousand radiocarbon years. Despite dedicated inter-laboratory comparison programs (e.g., Scott, 2003), the repeat dating of specific samples by different laboratories is rare so that independent testing of the validity of a result is the exception not the rule.

Although charcoal has traditionally been the preferred material for dating the Middle and early Upper Paleolithic, the advent of AMS dating technology has made it possible to use the much smaller amount of datable carbon in bone or antler. These materials have become increasingly important since they are more commonly available and often show clear traces of human modification. In consequence, there has been a strong emphasis on dating bone samples, and less on charcoal, so that many of the AMS dates today accepted as highly relevant for the discussion of the Middle to Upper Paleolithic transition are from carefully-selected hominin and humanly-modified bone samples.

Comparison of charcoal and bone date series from equivalent Middle and earlier Upper Paleolithic contexts has demonstrated a methodological problem, with significant differences between the two (cf. Joris et al., 2003, in press). The large series of available bone dates show an extremely broad distribution, with age
overlaps far beyond the associated statistical dating errors. This has often been taken as supporting a major temporal overlap (>10 ka 14C BP) between the Middle and Upper Paleolithic within specific parts of Europe, often interpreted in favor of late Neandertal survival (e.g., Zilhão, 2006b). By contrast, results on charcoal tend to be significantly older and consistently date the latest Middle Paleolithic sites to before ca. 38 ka 14C BP, whereas both IUP and EUP charcoal dates post-date ca. 38 ka 14C BP, suggestive for their successive appearance. The blurred picture given by bone measurements is most probably a result of younger contaminant carbon.

Recent developments in bone collagen extraction and purification (e.g., “ultrafiltration” pre-treatment: Bronk Ramsey et al., 2004) demonstrate convincingly that it is now possible to remove a far larger amount of younger contaminants from bone samples than was previously possible. In most cases the results are older ages for the same bone specimens previously dated without these procedures (Higham et al., 2006a,b; Jacoby et al., 2006; cf. Jacoby and Higham, 2008), leading to optimism that such techniques may indeed achieve more reliable measurements. On balance, this suggests that recently measured 14C-ages on bone produced by laboratories utilizing comparable state-of-the-art technology can be regarded with more confidence in terms of precision and reliability, although we must accept that we are only just beginning to fully understand the diverse problems of sample contamination, and that further improvements and corrections of the data are to be expected.

Over the past decade it has become increasingly evident that not only bone samples, but also charcoal from contexts at the older age limit of the radiocarbon method, potentially yield results which are far too young. This is a result of imperfect removal of modern or younger carbon from the sample by standard ABA (acid-base-acid) charcoal pretreatment. The presence of only a very small amount of recent contaminant will significantly reduce the age of a sample containing little remnant original 14C and can create a “barrier effect” with dates peaking at around 40 ka 14C BP and no older. This presents a problem analogous to that of bone samples.

Development of a new method (Bird et al., 1999), so-called acid-base-oxidation pretreatment followed by stepped combustion (ABOX-SC), suggested that it is possible to eliminate practically all contaminant carbon and push the effective limits of reliable charcoal dating back to at least 50 ka 14C BP, with subsequent refinements suggesting possible extension of its application back to 60 ka 14C BP (Pigati et al., 2007).

The development of the ABOX-SC method took place against the background of discussions of the timing of human colonization of the Australian continent, and much of its application has been in this context (Turney et al., 2001a,b,c; Bird et al., 2002, 2003a; Gillespie, 2002; O’Connell and Allen, 2004), although it has subsequently been employed in other contexts and geographical settings (e.g., Bird et al., 2003b; Santos et al., 2003; synthesis in Bird et al., 2004; Barker et al., 2007). Although this significant improvement in methods of charcoal radiocarbon dating covers exactly the period crucial to the questions addressed here (cf. Blockley et al., 2008), we are not aware of any published ABOX results from sites around the Middle to Upper Paleolithic transition in western Eurasia. However, dating work is reported in progress for layers relevant to this question at the key site of Willendorf II in Lower Austria (Nigst et al., 2008: 12).

The recent improvements in the application of ultrafiltration or ABOX techniques will surely lead to further advances in the alleviation or resolution of the described problems and will become standard procedures for radiocarbon dating at the Middle to Upper Paleolithic boundary. Nevertheless, we suggest that at present the accuracy of charcoal samples from this time range can probably be accepted as generally higher than that of bone (see above, cf. Jöris et al., 2003, in press). We recommend caution in the interpretation of 14C ages, particularly on bone samples with undemonstrated and/or inappropriate pre-treatment, and must accept that, at the limits of the dating method, an unknown proportion of radiocarbon results, both on these bone samples and on charcoal dated without ABOX-SC techniques, may be in many cases (much) too young and must therefore be regarded as minimum ages only (e.g., Turney et al., 2006).

The relevance of a dated sample for an archaeological/anthropological context cannot be assumed simply on grounds of spatial proximity, but must be supported by critical examination of its context and the taphonomic environment. Dates on samples from older excavations frequently have no or inadequate stratigraphic/spatial context control in comparison with today’s generally accepted standards (e.g., Pettitt et al., 2003). The often large bulk samples necessary for conventional β-decay radiocarbon dating (often composed of a variety of undiagnostic fragments) need to be treated with particular caution.

The archaeological/paleoanthropological relevance of a sample is most clearly given when it is unambiguously altered by human modification (e.g., cut marks on bone), and since the introduction of the AMS 14C method, the much smaller sample required has allowed many such documents of human activity to be dated (including valuable single objects of art or adornment), albeit with the proviso described above. Even then, direct dates on “significant” cultural proxies (e.g., artifacts such as bone, antler, or ivory points) can rarely be associated with a specific form of hominin and, in the majority of cases, direct dates on hominin fossils have no demonstrated relevance for the cultural/archaeological record (cf. Jöris et al., in press).

As has long been recognized, a direct comparison of the time scale provided by radiocarbon measurements with ages scaled to true calendar years is impossible without calibration, which becomes most evident when comparing with the age estimates given from other dating methods supplying absolute (calendric) ages (e.g., U/Th-series, TL). Despite lingering skepticism towards radiocarbon age calibration for most of the Last Glacial period (e.g., Reimer et al., 2004; van der Plicht et al., 2004; Bronk Ramsey et al., 2006), it now seems that remaining problems are far less significant than are errors due to sample contamination and context. Indeed, most recent progress has focused on the elaboration of a near-to-absolute age-model incorporating a synchronization of paleoclimate archives for the last 75 ka BP and promises a breakthrough in the calibration of the 14C time scale back to the technical limits of the method (cf. www.calpal.de; Weninger and Jöris, 2004, 2008; Hughen et al., 2006; cf. Blockley et al., 2008).

Direct dates for western Eurasian hominins at the Middle to Upper Paleolithic transition

Very few Neandertals or early AMH specimens have been directly dated. Of those relevant for the Middle to Upper Paleolithic transition in western Eurasia, only 19 direct radiocarbon measurements from 5 different sites and 2 uranium-series measurements have been made on Neandertal specimens, and 13 radiocarbon analyses have been made on European pre-Mid-Upper Paleolithic AMH.

Dates from five Neandertal sites form a coherent group (Fig. 3; See Table 1 in Supplementary Online Material [SOM]), demonstrating the presence of these hominins shortly before 38 ka 14C BP at the Kleine Feldhofer Grotte type locality in the Düsseldorf Valley of Germany (Schmitz et al., 2002), El Sidron in Cantabrian Spain (Lalueza-Fox et al., 2005), Rochers-de-Villeneuve, France (Beauval et al., 2005, 2006), the Kůlna Cave in the Czech Republic (Mook, 1988), and in layer G3 at the Croatian site of Vindija (Kriegers et al., 2000; Serre et al., 2004).
During the last few years direct dating has revised the paleoanthropological record of supposedly key-specimens for the question of early European AMH (Terberger et al., 2001; Terberger and Street, 2003; Conard et al., 2004; Street et al., 2006) with only a few directly dated fossils remaining relevant (SOM Table 1; cf. Churchill et al., 2000; Trinkaus, 2005, 2007; Jacobi and Higham, 2008).

Because of the fragmentary state of the Kent’s Cavern 4 maxilla, there is doubt as to its taxonomic affinity (Jacobi et al., 2006); however, the specimen has been linked with the Aurignacian material found at the site. Repeat dating of the specimen after ultrafiltration pre-treatment failed, but dates on stratified material bracketing its find horizon suggest that a previously obtained date (SOM Table 1) must be regarded as a minimum age estimate only, and that the true radiocarbon age might fall between ca. 37 and 35 ka 14C BP (Higham et al., 2006b).

With a combined radiocarbon age of 34,950 ± 990/890 14C BP (SOM Table 1), the Peștera cu Oase 1 mandible provides the earliest reliable dating evidence for AMH in Europe (Trinkaus et al., 2003), which is comparable in age with the directly 14C-dated early AMH from the Chinese Tianyuan Cave (Shang et al., 2007). The specimens from Mladecˇ, Czech Republic, date to ca. 31.2 ka 14C BP and are appreciably younger (Wild et al., 2005; SOM Table 1). Viewed from...
the circumstances of the discovery it appears that the latter remains are associated with an Aurignacian characterized by bone points of the eponymous Mladeč type of the later Aurignacian (Hahn, 1988a; Svoboda, 2000, 2003). AMH remains from the Romanian sites of Peștera Muierii de la Baia de Fier and Peștera Mare-Cioclovina (Trinkaus, 2007) are also probably associated with the Aurignacian and are directly dated to ca. 30 ka and 29 ka \(^{14}C\) BP, respectively (Paunescu, 2001; Sofiarcu et al., 2006; SOM Table 1). They are about the same age as the “Red Lady” AMH burial from Paviland, recently re-dated following ultrafiltration pre-treatment (Jacobi and Higham, 2008).

The direct dating evidence for western Eurasian Neandertal/early AMH specimens at present can be summarized as follows:

1. Reliable dates for Neandertal fossils are found only before ca. 38 ka \(^{14}C\) BP.
2. AMH fossils are not reliably dated to before ca. 35 ka \(^{14}C\) BP; however, the association of AMH with the Aurignacian can be accepted (e.g., Churchill and Smith, 2000; Paunescu, 2001; Trinkaus et al., 2003; Bailey and Hublin, 2005; Trinkaus, 2005; Wild et al., 2005).
3. The interval 38–35 ka \(^{14}C\) BP in western Eurasia has not yet provided unambiguous anthropological evidence for either Neandertals or early AMH, leaving room for discussion of cultural and/or genetic transfer between the two groups. An isolated context dated tooth from Kostenki 14, level IVb is discussed as AMH (Sinitsyn, 2003: 91), and in the Near East an early AMH burial (“Egbert”) uncovered at the site of Ksar‘Akil (Bergman and Stringer, 1989) in an Early Ahmarian context is placed into this gap (cf. Mellars, 2004; Zilhão, 2007).

Chronology of “transitional industries”

As frequently argued, the technological and typological features of certain “transitional” lithic industries suggest that they developed regionally from LMP substrates and can perhaps be regarded most parsimoniously as the last expression of indigenous Middle Paleolithic development (Bosinski, 1967; Bolus, 2004; Jóris, 2004). In other words, these industries represent a diverse and more differentiated “Final Middle Paleolithic” (FMP). We see no need to regard these industries as “transitional” in the sense of foreshadowing the “behavioral modernity” of subsequent Upper Paleolithic assemblages. With the exception of Neandertals from the two Chatelperronian contexts at St. Césaire (Lévêque and Vandermeersch, 1980; Morin et al., 2005; but see also discussion in Bar-Yosef, 2006b) and the Grotte du Renne at Arcy-sur-Cure (Leroi-Gourhan, 1958; Bailey and Hublin, 2006), none of the FMP group of “transitional industries” is associated with unambiguous or significant hominin remains. It nevertheless seems probable that all were made by the aboriginal Neandertal population.

Close in time to these FMP foliate and backed-point industries exist other southern and southeastern European “transitional industries” characterized by a significant blade component and “Upper Paleolithic” tool types, which appear to represent a break with previous Middle Paleolithic regional traditions. These industries have often been perceived as the earliest evidence for the Upper Paleolithic within the region (e.g., Kozlowski, 1982).

FMP curved-backed piece industries

The southwestern European Chatelperronian, initially considered to be fully Upper Paleolithic (e.g., de Sonneville-Bordes, 1960) but later shown to display Middle Paleolithic features as well (Leroi-Gourhan, 1968; Guilbaud, 1993; d’Errico et al., 1998; discussion in Zilhão and d’Errico, 1999), is characterized among other types by curved-backed pieces. Supported by a similar geographical distribution of sites and by techno-typological features, it has been claimed that the Chatelperronian arises from the latest regional Mousterian of Acheulian Tradition (e.g., Bordes, 1961; Pelegrin, 1995; Soressi, 2002; cf. Bosinski, 1989, 1990). Other “transitional” industries with curved-backed pieces—among them the Uluzzian of the Italian Peninsula (Palma di Cesnola, 1982) and the Layer V industry from Klisoura Cave 1 in Greece (Koumouzelis et al., 2001a,b)—may also be the result of filiation from a regional LMP, although others see a clear break between the Uluzzian and the preceding Italian Middle Paleolithic (e.g., Gioia, 1990).

In southern Italy, it seems certain that the Middle to Upper Paleolithic “transition” includes an Uluzzian curved-backed point phase followed by laminar industries ascribed to the Proto-aurignacian. Since Middle Paleolithic, Uluzzian, and Proto-aurignacian assemblages have never been demonstrated to overlie deposits of the Campanian Ignimbrite (CI) marker horizon (Fig. 1; Fedele et al., 2002, 2003, 2008; Giaccio et al., 2006), they must be more than ca. 40,000 calendar years old and should therefore date slightly before ca. 34.8–34.7 ka \(^{14}C\) BP, the approximate radiocarbon age of the CI eruption (Jóris et al., in press; Weninger and Jóris, 2008; cf. Fedele et al., 2008). If the Middle Paleolithic and Uluzzian industry from Ksar‘Akil has been made by Neandertals, the survival of these hominins on the Central and Eastern Mediterranean peninsulas later than ca. 39.6 ka \(^{14}C\) BP (Weninger and Jóris, 2008) appears increasingly unlikely. This is also implied by the age of the Uluzzian-like inventory of level V at Klisoura Cave 1 in Greece, which stratigraphically pre-dates a long Aurignacian sequence. The next overlying Aurignacian levels IV and IlIg / IlIe are dated as early as ca. 34.7 ka \(^{14}C\) BP (SOM Table 2) and provide a date before which the Uluzzian assemblage must have been deposited, corresponding approximately with the radiocarbon age of CI. The age of the underlying level V itself can only be inferred from two infinite dates obtained from two hearths and by a more recently obtained single finite measurement on a burnt bone of ca. 40.0 ka \(^{14}C\) BP (Koumouzelis et al., 2001a,b).

In contrast to the poorly dated FMP industries of the Eastern and Central Mediterranean, the western European Chatelperronian has produced a relatively large number of radiocarbon dates (Fig. 4; SOM Table 2), the majority of them from French sites. With one exception all dates are on bone when the material is known. The Chatelperronian radiocarbon dataset is, however, heterogeneous with regard to the laboratories involved, the date of sample submission, and the range of ages produced (from ca. 45 to 25 ka \(^{14}C\) BP). Many results have large standard deviations and several are clearly erroneous (for a recent compilation see Jóris et al., in press). The most comprehensive series of dates for the Chatelperronian comes from the site of Grotte du Renne (Arcy-sur-Cure: Fig. 4; SOM Table 2), where numerous radiocarbon determinations are available throughout a continuous stratigraphic sequence from the LMP to the Aurignacian (David et al., 2001). The site is of key importance in the discussion of late Neandertals due to the recovery of the greatest number of personal ornaments attributed to a Chatelperronian context (cf. discussion in Zilhão, 2007) and the preservation of Neandertal remains (Hublin et al., 1996; cf. Bailey and Hublin, 2006). The oldest Chatelperronian level X at Grotte du Renne provided a number of impossibly young dates. Although other results from the same level form a more plausible cluster around 34–33 ka \(^{14}C\) BP, it might be questioned whether the single date of 38,300 ± 1,300 \(^{14}C\) BP (OxA-8451/Ly-894) on a horse bone from layer Xb1 does not imply a much older age, similar to results from level BS at Grotte des Fées or level 8 at Roc-de-Combe. While the middle Chatelperronian at Grotte du Renne (level IX) has widely discrepant dates, seemingly too young relative to the stratigraphic sequence, dates for the youngest level (VIII) again form a group with ages between ca. 33.9 and 32.0 ka \(^{14}C\) BP. Due to
these inconsistencies, the Grotte du Renne radiocarbon dataset does not resolve the debate on the age of the Chatelperronian at this site. The fact that results are based on conventional measurement, often on bulked bone, suggests that their contextual, if not indeed their methodological validity, must be viewed critically.

**FMP leaf/blade point industries**

The northwestern and Central European leaf-point industries or *Blattspitzengruppen* (cf. Freund, 1952), characterized by (semi-) bifacially-worked foliate tools (leaf points and blade points: e.g., Jacobi, 1990), occur to the north of the high alpine mountain chains. The industries are variously described as Lincombian (Campbell, 1977; but see objection in Jacobi, 1990), Jerzmanovician, Altmühl-gruppe/"Ranisian," or "Szeletian"¹ (e.g., Allsworth-Jones, 1986; Bolus, 2004; Jacobi et al., 2006: 567). These "transitional industries" can convincingly be argued to have emerged from the LMP *Keilmessergruppen* industries of Central and Eastern Europe (cf. Bosinski, 1967; Jöris, 2004) and, in the view of the authors, can therefore be regarded as an autochthonous FMP development.

¹ The limited stratigraphic information, the questionable integrity of the lithic assemblages, and the unclear provenance of the radiocarbon-dated sample material from Széleta Cave, Hungary, do not provide conclusive information on the age of the Szeletian (cf. Lengyel and Mester, submitted). It might even be considered whether the term "Szeletian" should not be rejected completely.

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**Fig. 4.** Selection of results from radiometric dating of Chatelperronian and Uluzzian assemblages (see: SOM Table 2), given with 1σ-standard deviation. Dates on bone – circles (open–without traces of hominin activity); dates on charcoal – diamonds; unknown material – x; dark grey shading – most likely dating range; light grey shading – divergent dates.
Although limited, the most important stratigraphic evidence for the age of leaf point industries at the Middle to Upper Paleolithic transition comes from the German sites of the Weinberghöhlen close to Mauern (von Koenigswald et al., 1974) and the Ilsenhöhle in Ranis (Hüelle, 1977). Here there is no doubt that leaf point industries were below any Upper Paleolithic layers present (Bolus, 2004). To date, no reliable absolute dates are available for these sites. Recently obtained 14C AMS dates for the Ilsenhöhle at Ranis (Grüngberg, 2006) are unable to clarify the age of the foliate point assemblage. Results for supposedly distinct “Blattspitzen,” Aurignacian, and Gravettian contexts 2, 3, and 4 place all three entities indiscriminately within the period 33.5–27.0 ka 14C BP. The early date of the excavations (Hüelle, 1977) and the complicated and probably-disturbed site stratigraphy might explain why the sampled bones do not reliably date specific cultural units.

With reservations, a limited number of radiocarbon dates for leaf point industries forms a consistent group between ca. 40.0 and 27.0 ka 14C BP (Aldhouse-Green and Pettitt, 1998), the new AMS dates initially assigned these industries to ca. 29–27 ka 14C BP (Fig. 5; SOM Table 3). Five charcoal dates from Vedrovice V in the Czech Republic (Valoch, 1993, 1996; Svoboda, 2003) date the Bohunician here with a weighted mean of 38,642 ± 541 14C BP. Radiocarbon dates from the Czech site of Strašná skála obtained on charcoal from the “upper paleosol” (Damblon et al., 1996; Valoch, 1996; Svoboda, 2003) date the Bohunician here with a weighted mean of 35,726 ± 413 14C BP (OxA-5176: TD-I inf.) and 36,900 ± 1,300 14C BP (OxA-5173: TD-V inf.), as well as by two TL measurements (SOM Table 4). Three radiocarbon results from context TD-I (interior) give a weighted mean of 38,642 ± 954 14C BP. Radiocarbon dates from the Czech site of Stránská skála obtained on charcoal from the “upper paleosol” (Damblon et al., 1996; Valoch, 1996; Svoboda, 2003) date the Bohunician here with a weighted mean of 35,726 ± 213 14C BP (SOM Table 4). The assemblage of Korolevo II, layer II, in Transcarpathian Ukraine (Usik et al., 2006), also identified as a “Bohunickian-type” industry, dates to 38,500 ± 1,000 14C BP ([GIN]-2774) (Fig. 6; SOM Table 4). Assumed to be of comparable age is the non-Aurignacian EUP of Korolevo I, layer I-a (Usik et al., 2006), while the blade-dominated industry from area A, level 3, at Sokirnitsa I is dated by a highly consistent series of charcoal radiocarbon measurements to around 38,880 ± 110 14C BP (KI-10837) (Fig. 6; SOM Table 4; Usik et al., 2006).

IUP early laminar industries

The laminar “Bachokirian” assemblages from the Bulgarian sites Bacho Kiro, level 11, and Temnata TD-I and TD-V, layer 4, were originally assigned to the early Upper Paleolithic and seen as close to but distinct from the succeeding Aurignacian (e.g., Koztowski, 1992, 2006). Recent studies of their technology show that blade production differs in important details from that of the Aurignacian and is instead close to an evolved Levallois Mousterian. They display particular parallels to Near Eastern assemblages (e.g., Tsanova and Bordes, 2003; Teyssandier, 2006, 2007), and are generally grouped together into an “Initial Upper Paleolithic” (IUP; e.g., Bar-Yosef, 2003; Kuhn, 2003). The Bachokirian might, therefore, be classified as an “IUP transitional industry” that, although clearly rooted in the (not necessarily regional) Middle Paleolithic, already presents some aspects of Upper Paleolithic technology. The eastern Central European Bohunician is interpreted similarly (Škrdla, 1996, 2003; Svoboda, 2003; Svoboda and Bar-Yosef, 2003), but usually contains some foliates.

The Bacho-Kiro layer 11 industry is associated with three radiocarbon dates giving a weighted mean of 36,471 ± 796 14C BP (Fig. 6; SOM Table 4). At Temnata, the Bachokirian (Ginter et al., 1996) is overlain by the Y5 tephra layer of the CI and is dated by a series of radiocarbon measurements, mostly on charcoal, to between 39,100 ± 1,800 14C BP (OxA-5169: TD-I inf.) and 36,900 ± 1,300 14C BP (OxA-5173: TD-V inf.), as well as by two TL measurements (SOM Table 4). Three radiocarbon results from context TD-I (interior) give a weighted mean of 38,642 ± 954 14C BP. Radiocarbon dates from the Czech site of Stránská skála obtained on charcoal from the “upper paleosol” (Damblon et al., 1996; Valoch, 1996; Svoboda, 2003) date the Bohunician here with a weighted mean of 35,726 ± 213 14C BP (SOM Table 4). The assemblage of Korolevo II, layer II, in Transcarpathian Ukraine (Usik et al., 2006), also identified as a “Bohunickian-type” industry, dates to 38,500 ± 1,000 14C BP ([GIN]-2774) (Fig. 6; SOM Table 4). Assumed to be of comparable age is the non-Aurignacian EUP of Korolevo I, layer I-a (Usik et al., 2006), while the blade-dominated industry from area A, level 3, at Sokirnitsa I is dated by a highly consistent series of charcoal radiocarbon measurements to around 38,880 ± 110 14C BP (KI-10837) (Fig. 6; SOM Table 4; Usik et al., 2006).

Pre-Aurignacian EUP

(Protoaurignacian/”Aurignacien 0”/”Fumanian”/”Protoaurignacian”; Kostenki 14)

Around the northern Mediterranean a very early appearance of the Upper Paleolithic is suggested by dates for “Aurignacian 0”/“Protoaurignacian”/”Fumanian” horizons (Broglio and Laplace, 1966; Laplace, 1966; Mellars, 2006b) at sites such as L’Arbreda (Bischoff et al., 1989; Canal i Roquet and Carbonell i Roura, 1989; Ortega Cobos et al., 2005) and Abric Romani (Canal i Roquet and Carbonell i Roura, 1989; Bischoff et al., 1994) in Catalonian Spain or Riparo Mochi and Grotta di Fupane (Laplace, 1977; Broglio, 1996, 2000, 2001) in northern Italy. Here too, detailed technological analyses reveal close similarities with laminar production systems that derive from the Levallois Mousterian and suggest a relationship between the Mediterranean industries and broadly...
contemporary EUP industries of the Near East (e.g., Ohnuma, 1988; Boëda and Muhesen, 1993; Marks, 1993; Bourguignon, 1996; Kuhn et al., 1999; Bar-Yosef, 2000, 2003; Kuhn, 2004).

In the long stratigraphy of the southern Russian site of Kostenki 14, Aurignacian levels overlie two EUP horizons ("Cultural Layer IVb" and the "Horizon of Hearths") distinct from both the Aurignacian and the underlying LMP in their lithic technology (Anikovich et al., 2007). This EUP is characterized by the production of blades and bladelets from prismatic cores, bone, and ivory working.

Nicolas Teyssandier justifiably cautions that, in the case of European pre-Aurignacian blade assemblages, such as the Bachokirian, Bohunician, and Protoaurignacian/Fumanian, "the question remains totally open whether or not these typo-technological similarities represent technical convergences, diffusion of ideas, or human migrations" (Teyssandier, 2006:14). We nevertheless suggest that they most probably do represent the transfer of Near Eastern technologies and ideas into Europe by immigrating AMH.

The largest series of Protoaurignacian radiocarbon dates (Fig. 7; SOM Table 5) comes from layer A2 at Grotta di Fumane in northern Italy, which overlies a long Middle Paleolithic sequence dated by charcoal samples to between ca. 42.0 ka \(^{14}C\) BP (layer A11) and slightly older than 33.0 ka \(^{14}C\) BP (layer A4; Giaccio et al., 2006). Protoaurignacian horizon A2 is dated to between 36.8 and 31.3 ka \(^{14}C\) BP, with the best contextual information provided by Hearth S14 (Fig. 7; SOM Table 5; cf. Jöris et al., in press). Of seven charcoal samples taken here, five measurements give a pooled mean of 34,164 \(\pm 281\) \(^{14}C\) BP. In northwestern Italy at the site of Riparo Mochi (Mussi et al., 2006) radiocarbon dating places the Protoaurignacian close to 35.0 ka \(^{14}C\) BP, with the three oldest Mochi dates forming a tight cluster between 35.7–34.7 ka \(^{14}C\) BP (Fig. 7; SOM Table 5).

At Isturitz in southwestern France, the Protoaurignacian assemblage of layer 4d (Zilha˜o and d’Errico, 1999) is dated by the weighted mean of two radiocarbon measurements on charcoal to 35,490 \(\pm 413\) \(^{14}C\) BP (Fig. 7; SOM Table 5), while the oldest date for Aurignacian layer G at Tournal provides a minimum age \(>35,800\) \(^{14}C\) BP (Ly-1898) for the underlying Protoaurignacian levels F and C (Tavoso, 1976).

At Abric Romani in Spain, Protoaurignacian layer 2 ("layer A"), which most likely represents a living floor sealed by overlying travertine, produced "abundant faunal remains, dispersed charcoal, and artifacts" (Bischoff et al., 1994: 544), allowing seven radiocarbon measurements to be obtained on charcoal at three different locations of the site (Fig. 7; SOM Table 5). Five of these produced a weighted mean of 36,644 \(\pm 373\) \(^{14}C\) BP and are stratigraphically consistent with a radiocarbon date of 36,600 \(\pm 1,300\) \(^{14}C\) BP (USGS-2839) on charcoal embedded in the travertine, which is itself dated to between 42.9 and 39.1 ka \(^{14}C\) BP (Bischoff et al., 1994; Carbonell et al., 1994). The Protoaurignacian horizon at L’Arbreda has produced consistent radiocarbon age determinations significantly older than 36.5 ka \(^{14}C\) BP (Bischoff et al., 1989; Canal i Roquet and Carbonell i Roura, 1989; Fig. 7; SOM Table 5). Four charcoal samples from a 5 cm spit at the base of the Protoaurignacian deposits (Bischoff et al., 1989) produced a weighted mean of 38,307 \(\pm 552\) \(^{14}C\) BP (Jöris et al., in press). Since the samples derive from the deepest part of the Protoaurignacian level it is unclear whether they date the

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2 The fact that some of the Protoaurignacian radiocarbon measurements from the Grotta di Fumane produced dates significantly older than those of the underlying Middle Paleolithic horizons has been interpreted as resulting from extreme variations of past atmospheric \(^{14}C\) levels at the time of the Laschamp geomagnetic excursion (Giaccio et al., 2006). Similar arguments have been put forward to explain the high radiocarbon ages from Aurignacian layers at the Geißenklosterle (Conard and Bolus, 2003).

3 A radiocarbon measurement on bone assigned to the same cultural unit produced a somewhat younger age for this level (OxA-3730: 35,480 \(\pm 820\) \(^{14}C\) BP), although a radiocarbon measurement on bone located a few meters distant (CE 103) dates this level (H) to 37,340 \(\pm 1,000\) \(^{14}C\) BP (OxA-3729). A further measurement (Gif-6422) obtained earlier is considered to be too young (Fig. 7; SOM Table 5).
Protoaurignacian itself or simply provide a maximum age for the occupation (Zilhão and d’Errico, 1999; Zilhão, 2006b; cf. Soler Sublis et al., submitted). The consistency of radiometric dating and stratigraphic evidence at both L’Arbreda and Abric Romani strongly indicates that the earliest Protoaurignacian assemblages in the north of the Iberian Peninsula probably appear as early as 38.0–37.0 ka 14C BP.

A similar early appearance of the Protoaurignacian is suggested at the Grotta di Paina (Veneto, Italy), where two dates of 38,600 ± 1,400/1,800 14C BP (UtC-2042) and 37,900 ± 800 (UtC-2695) on bone from the base of archaeological level 9 (Fig. 7; SOM Table 5) provide a maximum age for the Protoaurignacian (Mussi et al., 2006).

At Kostenki 14 (Markina Gora) the two EUP horizons (“Cultural Layer IVb” and the “Horizon of Hearths”), overlain by the CI Y5 volcanic ash horizon (Anikovich et al., 2007), are dated to ca. 36,167 ± 176 14C BP (weighted mean of three dates from Layer IVb) and 35,964 ± 121 14C BP (weighted mean of five dates from the “Horizon of Hearths”), respectively (Fig. 7; SOM Table 5).

**Origins and innovations of the Aurignacian**

In contrast to the scenario of the spread of “progressive ideas” from the East to the West with the advent of early AMH in western Eurasia, recent studies of lithic technologies in southwestern France have instead suggested in situ evolution of the Aurignacian from the preceding Protoaurignacian and Chatelperronian substrate as a possibility (Bordes, 2006: 165). It can also be argued that “the Aurignacian” is not monolithic and that uncritical use of the term may artificially unite diverse chronological, technological, social, and possibly ethnic units. Equally, many elements that supposedly characterize the Aurignacian are regionally restricted, and hence, absent at some sites identified with this entity (cf. Vanhaeren and d’Errico, 2006). While laminar lithic technology and the use of personal ornaments may be elements “inherited” from earlier AMH traditions, such as the Protoaurignacian or Bachokirian (and ultimately the eastern Mediterranean initial Upper Paleolithic), other features seem to represent specifically Aurignacian innovations that characterize almost all of the Aurignacian assemblages. Among these are the
systematic production of (backed) bladelets by a distinct “chaine opératoire”; highly specific lithic tool-kits; elaborate and standardized antler, bone, and ivory projectile point technology; and figurative art, music, and—probably—specific belief or ritual systems (cf. Zilhão, 2007). At latest by the Aurignacian II phase we commonly find the full spectrum of “behaviorally modern” traits listed above. In this context it is important to examine claims based on the radiocarbon record for a precocious appearance of the Aurignacian in certain regions of Europe.

Arguments for a very early appearance of the Aurignacian in southern Central Europe (i.e., significantly before 35.0 ka 14C BP; the so-called “Danube Corridor” hypothesis of Conard and Bolus, 2003) have focused in particular on radiocarbon dates from the Lower Austrian site of Willendorf II, cultural layer (Kulturschicht: KS) 3, and the southern German sites of Keilberg-Kirche and Geißenklosterle (AH III – II).

The chronostratigraphy of the Willendorf II site is well-established (Damblo et al., 1996) and the basal horizons (KS 1–KS 4) fall at the transition from the Middle to the Upper Paleolithic. While basal KS 1 and KS 2 produced very small assemblages lacking diagnostic artifacts (Haesaerts and Teyssandier, 2003: 144; Teyssandier et al., 2006: 247), the youngest, unquestionably Aurignacian KS 4 has radiocarbon dates between ca. 32.0 and 30.0 ka 14C BP. KS 3 is stratified below KS 4 and has traditionally been assigned to an (early) Aurignacian (e.g., Felgenhauer, 1959; Broglie and Laplace, 1966; Hahn, 1977; Teyssandier, 2007). Preliminary evaluation of numerous, hitherto unpublished artifacts from the excavations of Szombathy, Bayer, and Obermaier (Nigst, 2004) support an attribution to a fully Aurignacian context (Nigst, 2004, 2006).

Of three radiocarbon charcoal measurements for KS 3 (Damblo et al., 1996), two provide a weighted mean slightly older than 38.1 ka 14C BP (GRN-17805: 38,880 ± 1,530/−1,280 14C BP; GR-896: 37,930 ± 750 14C BP), while a third measurement produced a significantly younger date of 34,100 ± 1,200/−1,000 14C BP (GRN-11192). Whereas most recent studies (Haesaerts and Teyssandier, 2003; Nigst, 2006) tend to accept the older age of around 38.0 ka 14C BP for KS 3, Zilhaão and d’Errico (1999) have suggested that the older samples may be reworked and that GRN-11192 represents the “true” age of the assemblage. The submission of new radiocarbon samples from recent fieldwork at the site (www.willendorf-project.org; Nigst, pers. comm.) may help to clarify this problem (Nigst et al., 2008: 12).

Charcoal samples from a small (4 m2) rescue excavation carried out in 1987 at Keilberg-Kirche, close to Regensburg in Bavaria, provided three statistically identical radiocarbon measurements with a weighted mean of 37,922 ± 743 14C BP4 (i.e., approximately the same age as the older age estimates for Willendorf II, KS 3). The charcoal and burnt bone were associated with what was probably an in situ hearth, together with 215 artifacts including typically Aurignacian forms and burnt pieces (Uthmeier, 1996, 2004). In 1991 a test excavation over an area of some 250 m2 recovered a further 721 artifacts (Uthmeier, 1996).

The presence in some test pits of a few, not very diagnostic but probable Middle Paleolithic artifacts (Uthmeier, 1996) led to the suggestion that the hearth might be linked to an older occupation phase at this locality (Zilhaão and d’Errico, 1999). However, since typical Aurignacian artifacts were documented in spatial association with areas of burnt loess around the hearth, the most parsimonious interpretation would be that the dates apply to the Aurignacian (Uthmeier, 1996). This interpretation is unsupported by independent dating methods.

Of great importance for the earliest Aurignacian in Central Europe is the stratigraphic sequence of archaeological horizons (AH) III and II at Geißenklosterle in southwestern Germany (Hahn, 1988b; Conard et al., 2003). Recent excavations and comprehensive refitting work have confirmed the integrity of the different assemblages and the previous stratigraphic interpretations of the site (Conard et al., 2003, 2006; contra Zilhaão and d’Errico, 1999). Joachim Hahn distinguished the Aurignacian of AH II, which provided all the Geißenklosterle figurative art, from the stratigraphically earlier AH III (Hahn, 1988b) and suggested that AH II compares favorably with the French early Aurignacian (Aurignacian I), particularly due to the similarities of the organic technology. The interpretation of AH III is more difficult. Although Hahn eventually came to designate AH III as “Protoaurignacian” (Hahn, 1995), this was perhaps under the influence of the first 14C AMS ages for the horizon, which were unexpectedly old and similar to results for the Spanish Protoaurignacian. Such ages suggested that AH III might represent an early “true” Aurignacian phase chronologically preceding the “classical Aurignacien I” (Hahn, 1988b: 246). Recent analyses of technological aspects of both the lithic and organic material have confirmed that the entire Geißenklosterle sequence from horizons AH IIIb–IIa is fully Aurignacian in character, without any “Protoaurignacian” characteristics (e.g., Bolus, 2003; Teyssandier and Liolios, 2003; Teyssandier, 2006, 2007; Teyssandier et al., 2006).

The large series of radiocarbon measurements on bone and charred bone from the Geißenklosterle Aurignacian sequence spans the period between 40,200 ± 1,600 14C BP (OxA-4595) and 28,640 ± 380–360 14C BP (KIA-8962) and is therefore claimed to provide some of the earliest evidence for the Aurignacian in Central Europe (Hahn, 1995; Bolus and Conard, 2001; Conard and Bolus, 2003; Conard et al., 2003). AH III is also dated to ca. 40 ka BP by thermoluminescence measurements on burnt artifacts (Richter et al., 2000). It is important to note that the Geissenklosterle radiocarbon results are often inconsistent with the stratigraphic provenance of the sample, with a number of the older dates coming from higher levels than much younger measurements (Conard et al., 2003: 173). These age-distortions have been explained as resulting from a “Middle to Upper Paleolithic dating anomaly” (cf. Conard and Bolus, 2003), indications for which have been claimed in a speleothem record from the Bahamas (Beck et al., 2001). In fact, the majority of radiocarbon dates for Geißenklosterle AH IIIb–IIA Ia are bracketed between 34,800 ± 290/−280 14C BP (KIA-13074) for AH IIIa, and 29,800 ± 240 14C BP (KIA-8960) for AH IIb. A critical examination of the radiocarbon samples with reference to their relevance for hominin activity and their stratigraphy suggests that the best estimate for the age of the Geissenklosterle Aurignacian is between ca. 34.8–33.2 ka 14C BP for the older phase (AH IIII) and around 33.2–29.8 ka 14C BP for the younger phase (AH II; cf. Zilhaão and d’Errico, 2003a; Teyssandier, 2005; Verpoorte, 2005; Jöris et al., in press).

On balance, the radiocarbon record for the Swabian Aurignacian agrees well with the dating of other Aurignacian sites (cf. Zilhaão and d’Errico, 1999; Djindjian et al., 2003; Jöris et al., in press). The Aurignacian appears quasi simultaneously across the whole of Europe from ca. 35 ka 14C BP (Fig. 2b), which is around the age of the CI eruption. Wherever this stratigraphic marker is present, the Aurignacian consistently overlies it. In Eastern Europe the Aurignacian overlies the CI Y5 tephra at Temnata and is found at Kosmata mixed with Y5 tephra in a cryoturbated layer that—most likely—formed during the Heinrich 4 cold interval (Hoffecker et al., 2008) shortly after ca. 40.0 ka BP (KIA-8962) and forms the CI Y5 tephra at Temnata and Kosmata mixed with Y5 tephra in a cryoturbated layer that—most likely—formed during the Heinrich 4 cold interval (Hoffecker et al., 2008).
into areas outside the fall out. This would have had a far reaching and, in the medium-term, probably catastrophic influence on southern and southeastern European environments (Fedele et al., 2002, 2003, 2008).

**Aurignacian innovations:**

standardized weapon technology and figurative art

Following its first appearance the Aurignacian develops greater cultural complexity, with different aspects of the full canon of Aurignacian material culture accumulating with time (Zilhão, 2007).

Series of direct radiocarbon dates on Aurignacian bone, antler, and ivory projectile points place the split-based points characteristic of Aurignacian I or points with massive bases of so-called “Mladeč” (aka “Lautsch”) type (regarded as typical for the later Aurignacian; e.g., Hahn, 1988a, c; Hofreiter and Pacher, 2004; Bolus and Conard, 2006) into a fairly narrow time range between 32.5–29.2 ka $^{14}$C BP (KIA-19551: 32,470 ± 270/$^-$/260 $^{14}$C BP; Bolus and Conard, 2006; OxA-13048: 29,210 ± 210 $^{14}$C BP; Grünberg, 2006)$^\text{5}$. A context radiocarbon measurement (GifA-101459: 32,650 ±540 $^{14}$C BP) for an ivory point with massive base from the “Galerie des Mégacéros” at Grotte Chauvet (Valladas et al., 2005) is only marginally older than directly-dated Central European specimens, suggesting that the emergence of standardized bone, antler, and ivory projectile point technology occurs at around 32.6/32.5 ka $^{14}$C BP in both Central and southwestern Europe. Bolus and Conard (2006) point out that the stratigraphical distinction between older (Aurignacian I) split-based and younger Aurignacian massive-based points recognizable in southwestern Europe (cf. Djindjian et al., 2003) is not reflected by the direct dates for Central European Aurignacian projectiles. However, in Central Europe, unambiguous direct dating evidence for split-based points is restricted to the single specimen T-143 from Tischsoferhöhle (Bolus and Conard, 2006) securely attributed to this type.

The oldest known portable figurative art originates from Aurignacian levels at Geißenklösterle (AH II), Vogelherd, Hohle Fels, Hohlenstein-Stadel in southwestern Germany (Hahn, 1987), and Stratzing (Krems-Rehberg) in Lower Austria (Neugebauer-Maresch, 1989). Geißenklösterle AH II dates to between 33.2 and 29.8 ka $^{14}$C BP (see above), with similar radiocarbon ages for comparable horizons at the other sites (Jorís et al., in press).

Although portable figurative art is unknown in Aurignacian contexts outside southern Central Europe, it is now generally accepted that the parietal figurative art from Grotte Chauvet is approximately contemporary (Valladas et al., 2001, 2005; but see Zürcher, 1996, 2003; Pettitt and Bahn, 2003; Pettitt, 2008). Radiocarbon direct dating of charcoal paintings produced results between 32,410 ± 720 $^{14}$C BP (GifA-95132) and 29,670 ± 950 $^{14}$C BP (GifA-98160) in complete agreement with other dating evidence for pre-Mid-Upper Palaeolithic hominin presence in the cave. It is also noteworthy that the suite of animal species depicted at Chauvet is in close agreement with those selected for the south-west German ivory carvings (cf. Floss and Rouquerol, 2007).

The dating results for the Grotte Chauvet paintings suggest that polychrome figurative parietal art first appears in western Europe within a younger phase of the Aurignacian, as is the case for the intentionally-colored limestone fragments that have been uncovered from Aurignacian horizons at several caves and rockshelters, among these Abri Blanchard (Breuil, 1952; Delluc and Delluc, 1978), Abri Pataud (Movius, 1975), and at the base of horizon AH II (AH IIb) at Geißenklösterle (Hahn, 1988b). Painted limestone blocks recovered at the Grotta di Fumane in northeastern Italy from an Aurignacian horizon dated to between 32.3 and 30.3 ka $^{14}$C BP show at least five red figurative depictions, among these possibly two anthropomorphs (Broglio et al., 2005: 46–47). The supposed age of all this evidence is in agreement with contextual dates for limestone blocks from southwestern France with deeply picked figurative and symbolic depictions that led André Leroi-Gourhan (1971) to the definition of his “Style 1” art. When stratigraphic control is adequate, these also appear to be associated with the later Aurignacian, dating younger than ca. 32.0 ka $^{14}$C BP (cf. Zilhão, 2007).

In summary, on the evidence of directly dated material; standardized bone, antler, and ivory weapon technology; and figurative art featuring anthropomorphs, therianthropes, and a particular suite of animal depictions were not part of the primary Aurignacian “package,” but represent later developments within specific (interlinked) Western and Central European Aurignacian core regions (cf. “Aurignacian Homeland”: Bar-Yosef, 2006a).

**Late Neandertal survival?**

The dating evidence compiled above shows that the temporal overlap of the Middle Paleolithic and Upper Paleolithic must have been limited to a few thousand radiocarbon years. If, as discussed above, the Protoaurignacian, Bachokirian, and the somewhat younger Aurignacian were produced by immigration of AMH, whereas FMP industries were the work of the last aboriginal European Neandertals, the period for interaction between the two hominin forms would have been, at most, of brief duration. In fact, over most of Europe, stratified sequences with Middle Paleolithic or “transitional” and Aurignacian or other Upper Paleolithic assemblages show an unambiguous succession with the former underlying the latter and only sparse and controversial arguments for interstratification (Jorís et al., in press). Indeed, sites in the Swabian Jura regularly show a clear hiatus between Middle and Upper Paleolithic horizons (Conard et al., 2006) and it seems clear that Aurignacian assemblages here postdate the Middle Paleolithic industries by an appreciable length of time.

Despite the idea that AMH would arrive latest on the Iberian Peninsula at the western extremity of the proposed AMH expansion, radiocarbon dates for both the Aurignacian and the Protoaurignacian in the northern part of the peninsula are no younger than elsewhere in Europe (Fig. 2a, b). For the southern part of the Iberian Peninsula, where neither Protoaurignacian nor Aurignacian I sites with characteristic split-based points are known, it is conceivable that the Aurignacian only arrives at a later date (Vega Toscano, 1990; Zilhão, 1993, 2006b). On the other hand, although the radiometric evidence for the period is particularly poor in this region (cf. Zilhão, 2006b), radiocarbon dates from Cova Beneito (AA-1388: 33,900 ± 1,100 $^{14}$C BP) in the region of Valencia and at Bajondillo (Ua-17150: 33,690 ± 1,195 $^{14}$C BP) in Andalucía suggest an Aurignacian presence only marginally younger than to the north (Fig. 2b). In this case, the absence of split-based points in Southern Iberia might simply characterize a particular Aurignacian facies rather than a chronological stage within the Aurignacian succession.

On the above evidence, we can neither confirm late Neandertal survival nor do we recognize a significant delay in the appearance of the Protoaurignacian/Aurignacian on the Iberian Peninsula. The scarcity of well-dated archaeological evidence in Southern Iberia during the crucial period from ca. 38–35/34 ka $^{14}$C BP might suggest alternative models. Regional population shifts due to climatic and environmental change at a millenial to centennial scale may have partially or wholly emptied the region of humans between the LMP and the Aurignacian (Jorís et al., 2003). Such a scenario could explain the absence of “transitional” industries, such as the

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$^5$ The direct result on a bone point from Aurignacian level V at Sirgenstein is slightly younger (KIA-13082: 26,730 ± 170/$^-$/160 $^{14}$C BP; Bolus and Conard, 2006), but the distal fragment does not permit a more precise typological attribution.
Chatelperronian and/or the Protoaurignacian, to the south of the Ebro River. By contrast, the dense presence of both groups in southwestern France and the northern Iberian Peninsula suggests that these were probably the regions and contexts in which contact between Neandertals and AMH would potentially have taken place.

In Western Europe, the stratigraphic evidence consistently shows that the Chatelperronian lies between LMP and Protoaurignacian levels around the Pyrenees and in Mediterranean France (Djindjian et al., 2003) and between LMP and Aurignacian I levels in the rest of France (Demars, 1996; Djindjian et al., 2003). The most comprehensive radiometric evidence for apparently younger Chatelperronian assemblages (dated significantly after ca. 35 ka \(^{14}C\) BP; Fig. 4) comes from layers X–VIII of the Grotte du Renne at Arcy-sur-Cure. However, the extreme range of variation shown by the radiocarbon dates (David et al., 2001) may indicate major stratigraphical and taphonomical problems at this locality (cf. White, 2001; Jorís et al., in press).

Although claims for interstratification of the Chatelperronian and Aurignacian have been made at El Pendo in northern Spain and at the French sites of Roc de Combe and Le Piage, these have been convincingly refuted in the recent past (d’Errico et al., 1998; Zilhão and d’Errico, 1999, 2003b; Rigaud, 2001; Djindjian et al., 2003; Bordes, 2006). Renewed claims for interstratification of both types of assemblages within the sequence of the Grotte des Fées (Chatelperron type site; Gravina et al., 2005) have been similarly challenged, with doubts regarding the integrity of both the stratigraphic sequence and lithic inventories (Zilhão et al., 2006).6

At present there is no convincing radiometric evidence and, perhaps more importantly, no proven case of interstratification which would support the contemporaneity of AMH and Neandertals. Proposed evidence for the survival of Neandertals on the Southern European peninsulas (most recently in Zilhão, 2006b) or in other supposed geographical refugia significantly later than ca. 38 ka \(^{14}C\) BP appears highly suspect.

Conclusions

Current radiometric and stratigraphic evidence suggests that Neandertal extinction was a rapid process that probably started around 39–37 ka \(^{14}C\) BP ago. The first appearance of Upper Paleolithic technologies suggest that Anatomically Modern Humans (AMH) arrive in Europe at around this time. At latest by ca. 35 ka \(^{14}C\) ago AMH were the only European hominins. This scenario supports neither a long coexistence of Neandertals and AMH nor the persistence of long-term geographical boundaries/borders during the process of AMH expansion (e.g., Vega Toscâo, 1993; Zilhão, 1993). Instead, the chain of demographic “events” within this period might be summarized as follows (Fig. 8):

(1) Industries such as the Chatelperronian and the Uluzzian in the southern part of Europe and the leaf or blade point industries to the north (all here interpreted as a “final Middle Paleolithic,” FMP) largely derive from regional late Middle Paleolithic substrates. The only hominin evidence from these contexts is provided by Neandertals remains from Arcy-sur-Cure and Saint Césaire, both associated with the Chatelperronian. Available dates place Chatelperronian assemblages broadly between ca. 41 and 38 ka \(^{14}C\) BP, although the majority of measurements has turned out significantly younger. While the limited radiocarbon evidence for the Uluzzian appears to suggest ages as young as 32–31 ka \(^{14}C\) BP, Uluzzian assemblages are stratigraphically overlain by the Campanian Ignimbrite (Castelcivita) or tephras correlated with this, placing the Uluzzian earlier than ca. 34.8/34.7 ka \(^{14}C\) BP (i.e., \(~40.0\) ka BP); cf. Weninger and Jorís, 2008; Fig. 8).7 The single finite date for the Uluzzian-like assemblage of Kisoura V in Greece (GIFa-99168: 40,010 ± 740 \(^{14}C\) BP) supports a comparably high age. Of similar age are the blade and leaf point assemblages of northern Europe, which are placed between 40.0 and 37.5 ka \(^{14}C\) BP by the available radiocarbon dating evidence.

(2) In contrast to the FMP “transitional” industries, a second group with specific laminar lithic production strategies displays technological similarities with the Near Eastern initial (IUP) and early Upper Paleolithic (EUP) and, in our opinion, best interpreted as of exogenous origin. Radiocarbon dates for the southeastern European Bachokirian IUP at the type locality and at Temnata cluster tightly between ca. 39.1 and 36.9 ka \(^{14}C\) BP (Fig. 8). The Bachokirian overlaps in time with the Bohunician to the north, which covers the time span ca. 38.5–36.4 ka \(^{14}C\) BP, although a small group of dates is as young as ca. 34.5 ka \(^{14}C\) BP (Fig. 8). The Bohunician resembles the Bachokirian but contains foliate points suggestive of affinities with FMP leaf-point industries. Although undemonstrated, the Bohunician might represent transfer or mixing of technology between pre-existing Neandertal populations and an AMH population responsible for the appearance of the Bachokirian in Eastern Europe.

The EUP Protoaurignacian (“Aurignacian 0”) found along the northern Mediterranean is dated to ca. 37.9–34.7 ka \(^{14}C\) BP or only slightly younger (Fig. 8). It is characterized by a lithic technology focusing on the production of both blades and bladelets within the same chaine opératoire, which is technologically and typologically distinct from preceding industries in the region but similar to the Eastern Mediterranean IUP. Equally old radiocarbon dates have been obtained for the EUP level IVB industry at Kostenki 14, falling between ca. 36.5 (or possibly 37.2) and 35.0 ka \(^{14}C\) BP. These EUP industries are associated with the regular use of marine shell ornaments.

Personal ornaments from layer H at Üçagızlı in southeastern Turkey (e.g., Kuhn et al., 2001; Stiner, 2003; Stiner et al., 2003) are the earliest securely dated ornaments outside Africa8. Layer H is dated to between 41.4 and 35.7 ka \(^{14}C\) BP with a weighted mean of four dates of 38.036 ± 487 \(^{14}C\) BP (Joris et al., in press). Less well-dated shell beads from IUP levels at the Lebanese site of Ksar‘Akil may be slightly older (Kuhn et al., 2001; Kuhn, 2004).

The practically simultaneous appearance of marine shell personal ornaments at the western end of the Mediterranean (L’Arbreda and Abric Romani), in the Danube Basin (Kremshundsteig), and areas adjacent to the Black Sea (Kostenki 14, IVb) so close in time to their occurrence at Üçagızlı (e.g., Stiner, 2003; Stiner et al., 2003) implies a very rapid diffusion of this concept. This phenomenon probably reflects the emergence of

6 It is claimed that stratigraphical problems at the Grotte des Fées were underestimated and that typological arguments are questionable (Zilhão and Pettitt, 2006; 7; Zilhão et al., 2006). Nevertheless, Mellars et al. (2007) insist that an ephemeral Aurignacian presence is documented stratigraphically between two Chatelperronian layers, interpret two consistent series of bone radiocarbon results as dating older and younger Chatelperronian occupations, and conclude that the Aurignacian at the site “could easily date from as late as, say, 36,000–37,000 BP” (Mellars et al., 2007: 3662).

7 It has been discussed (Giaccio et al., 2006) that due to an age inversion indicated for the critical period around 40.5 ka \(^{14}C\) BP Hulu towards the end of the Last Glacial Maximum (LGM), parts of the North African record may be substantially older (cf. Fedele et al., 2008; Weninger and Jorís, 2008).

8 The small amount of evidence for bead ornaments from appreciably older contexts (cf. Vanhaeren et al., 2006) represents a distinct, earlier but temporary dispersal of AMH out of Africa where the use of these items seems to have originated (Bouzouggar et al., 2007, and discussion therein).
large scale and elaborate social networks at this time, most plausibly established by newly arrived human groups that rapidly spread through Europe. The taxonomic identity of the groups might be indicated by an apparently AMH tooth from Kostenki 14, level IVb (Sinitsyn, 2003) and an AMH burial from Ksar’Akil (“Egbert”: Bergman and Stringer, 1989). Intriguingly, it has been recently suggested that the Protoaurignacian assemblage of Le Piage level K shows affinities with the underlying Chatelperronian (Bordes, 2006: 165), raising the possibility of some technological influence between FMP and EUP traditions comparable to the scenario considered above for the Bohunician in eastern Central Europe.

(3) The third element in the proposed sequence—the Aurignacian sensu stricto (excluding the Protoaurignacian/Aurignacian 0/Fumanian)—is fully Upper Paleolithic in character. Regional variations within a number of “cultural” categories (e.g., organic technology, art, etc.) show that the label unites diverse social and ethnic entities across its broad geographical and chronological range. Contrasted with this diversity, the lithic technological unity of the Aurignacian phenomenon has been repeatedly recognized.

Among ideas advanced for the origins of Aurignacian technology is a “...non-European origin for industries of Aurignacian type” corresponding “to the migration of the first modern humans to Europe” (Kozlowski and Otte, 2000: 513). However, an in situ evolution of the Aurignacian from the preceding Protoaurignacian has recently been suggested for the sites of Le Piage (Bordes, 2006) and, possibly, Arca-sur-Cure (Bon, 2006). Similarly, it has been proposed that the Eastern European Aurignacian might have developed from earlier laminar industries, such as the Bachokirian (Kozlowski, 2006: 33). The earliest appearance of fully Aurignacian lithic technology has been claimed for the Central European assemblages of Keilberg-Kirche and Willendorf II, KS 3, with radiocarbon ages between ca. 38.9 and 37.5 ka $^{14}$C BP. This would make them partially contemporary with both the Bachokirian and the Protoaurignacian, however the radiometric database is not very solid (see discussion above) and the industries are in no way transitional. Viewed critically, the radiocarbon evidence speaks, instead, overwhelmingly for the simultaneous appearance of Aurignacian lithic technology across Europe at ca. 35.0 ka $^{14}$C BP (more likely starting from 34.8 ka $^{14}$C BP; Fig. 8). Aurignacian figurative art is not documented before ca. 33.0/32.5 ka $^{14}$C BP, which broadly corresponds to the later Aurignacian “Mladecˇ phase” (32.5–29.2 ka $^{14}$C BP).

Following calibration of the radiocarbon time scale, the entire chain of demographic “events” suggested by the archaeological and paleoanthropological record can be referred to the course of climate change provided by the Greenland ice cores (Fig. 9).

FMP “transitional” industries (Uluzzian, Chatelperronian, leaf-point industries) are centered around Greenland Interstadial (GI) 11. The youngest reliably dated remains of Neandertals, the probable makers of these industries, are no younger than ca. 42.5 ka cal BP$_{Hulo}$ at the transition from GI 11 to Greenland Stadial (GS) 11. The IUP/EUP “transitional” industries (Bachokirian, Protoaurignacian, Kostenki 14, IVb) first appear across the southern half of Europe at approximately the same time. Remains of AMH, the probable makers of the IUP/EUP, are first directly dated to ca. 40.0 ka cal BP$_{Hulo}$.

Throughout Europe the EUP is replaced by the Aurignacian some 40,000 years ago, coincident with the Campanian Ignimbrite eruption at the onset of the Heinrich 4 cold interval (GS 9; Fig. 9). It is certain that both events would have had a major impact on western Eurasian ecosystems (cf. Fedele et al., 2002, 2003, 2008), leading to a serious loss of territory available to hominins. In peninsular Italy the CI event marks a rupture in settlement continuity between the EUP and the Mid-Upper Paleolithic (Fedele et al., 2002, 2003, 2008), while the climatic decline, which culminates in the Heinrich 4 event, led to deforestation of boreal environments in northern Europe (cf. Sirocko et al., 2005) and increased aridity on the Iberian Peninsula (cf. e.g., d’Errico and Sánchez Goñi, 2003) and possibly over much of southern Europe.
This may have caused regional hominin extinctions in some parts of Europe and migrations of populations between different regions. In the case of AMH, increased regional concentration of individuals served as a catalyst for the sudden pan-European appearance of the Aurignacian. Once set in motion, an accelerated flow of information ultimately led, not only to continued technological progress, but also, during the later Aurignacian, to innovative social adaptations in the form of art, music and, probably, religious beliefs.

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Appendix Supplementary materials

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jhevol.2008.04.002.

References


