On the chronology of the Uluzzian

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Abstract

The Uluzzian, one of Europe’s ‘transitional’ technocomplexes, has gained particular significance over the past three years when the only human remains associated with it were attributed to modern humans, instead of Neanderthals as previously thought. The position of the Uluzzian at stratified sequences, always overlying late Mousterian layers and underlying early Upper Palaeolithic ones, highlights its significance in understanding the passage from the Middle to Upper Palaeolithic, as well as the replacement of Neanderthals by modern humans in southeastern Mediterranean Europe. Despite several studies investigating aspects of its lithic techno-typology, taxonomy and material culture, the Uluzzian chronology has remained extremely poorly-known, based on a handful of dubious chronometric determinations. Here we aim to elucidate the chronological aspect of the technocomplex by presenting an integrated synthesis of new radiocarbon results and a Bayesian statistical approach from four stratified Uluzzian cave sequences in Italy and Greece (Cavallò, Fumane, Castelcivita and K Issoura). In addition to building a reliable chronological framework for the Uluzzian, we examine its appearance, tempo-spatial spread and correlation to previous and later Palaeolithic assemblages (Mousterian, Protoaurignacian) at the relevant regions. We conclude that the Uluzzian arrived in Italy and Greece shortly before 45,000 years ago and its final stages are placed at ~39,500 years ago, its end synchronous (if not slightly earlier) with the Campanian Ignimbrite eruption.

Keywords: Modern humans Neanderthals Radiocarbon dating Italy Greece

Introduction

In 1964, Arturo Palma di Cesnola coined the term ‘Uluzzian’ to describe the technocomplex he identified a year earlier at Cavallo Cave (Grotta del Cavallo) in southern Italy (Palma di Cesnola and Borzatti von Löwenstern, 1964). The distinct, dark Uluzzian layers overlay a long series of Mousterian deposits and were superposed by a late Upper Palaeolithic (Late Epigravettian) phase from which they were separated by a thin stalagmitic crust and a tephra layer. The Uluzzian layers were rich in lithic elements of Upper Palaeolithic character, terrestrial and marine faunal remains and several hearths. They contained bone points, perforated shell beads, mineral pigments, as well as two human deciduous teeth. The technocomplex was assigned to the Upper Palaeolithic (‘Lep-tolithic’) tradition, yet archaic at its lower layers, due to the presence of particular tool-types (lunates) that do not exist in the preceding Mousterian levels. Palma di Cesnola immediately recognized parallels with the Franco-Cantabrian Châtelperronian, and efforts to elucidate the geographical, techno-typological and chronological span of the Uluzzian, as well as its role in the Middle-to-Upper Palaeolithic transition, began.

In 2011, almost 50 years after the initial discovery of the technocomplex, the Uluzzian was brought to the forefront again. The two deciduous teeth from Cavallo Cave, the only human remains associated with the Uluzzian so far, were identified as belonging to anatomically modern humans and not Neanderthals, as was the consensus until then (Benazzi et al., 2011). The parallel radiocarbon dating of associated shell beads found across the Cavallo Uluzzian stratigraphy rendered the teeth the oldest currently-known remains of modern humans in Europe (Benazzi et al., 2011).
The geographic span of the Uluzzian has remained almost unchanged over the last decades and several authors have described the techno-typological features of the assemblages assigned to it. The chronology of the Uluzzian, however, remained poorly understood. Given the importance of the technocomplex in our understanding of the appearance and spread of modern humans in Europe, a chronological synthesis is long due and is the main focus of the present article.

Background

Geography

The presence of the Uluzzian has been reported in about 20 caves and open-air localities of peninsular Italy (Palma di Cesnola, 1989, 1993; Riel-Salvatore, 2007, 2009; Ronchitelli et al., 2009). These include sites mainly in Apulia (Cavallo, Uluzzo, Parabita, Mario Bernardini, Serra Cicora, Torre Testa, Falce del Viaggio, Foresta Umbra), Basilicata (Atella Basin), Campania (Cala, Castelcivita, Tornola), Calabria (San Pietro a Maida, Punta Sacco), Tuscany (La Fabbrica, Poggio Calvello, Val Berretta, San Romano, Indicatore, San Leonardo, Salviano and Maroconne) (Palma di Cesnola, 1989, 1993 and references therein). More recently, the presence of the Uluzzian at Fumane, Verona, was reported and this is currently the northernmost occurrence of the technocomplex (Peresani et al., 2008; Peresani, 2012).

A single occurrence outside Italy, at the Greek cave of Klissoura 1, Argolis, was described by Koumouzelis et al. (2001). This was later questioned by Papagianni (2009), but has since been reconfirmed by the excavators (Kaczanowska et al., 2010). Another Greek Uluzzian context from Kephali Cave, also in Argolis, was reported on anecdotal evidence (Hahn, 1984). This is currently being re-examined and more data will become available soon (G. Marshall, Personal communication).

Lithic technology-typology

The Uluzzian is a flake-dominated industry (Palma di Cesnola, 1993) that brings together a set of technological innovations (e.g., De Stefani et al., 2012). The production scheme is characterized by variable methods and techniques and a significant reduction in predetermined forms, when compared with the final Mousterian. The increased importance in the launch of various reduction sequences cannot be attributed to the qualities of the raw material only, but must assume behavioural significance too.

Blanks are detached using a unipolar method, with a single striking platform by direct percussion, and from a bipolar knapping on an anvil, which produces splintered pieces used mainly as wedges on medium-hard material. The principal objective was the production of average-thickness flakes and laminar flakes, sometimes naturally backed. Small blades and a small number of bladelets were also obtained. Few orthogonal, multi-directional and surface centripetal cores are also present (Palma di Cesnola, 1965a, 1966a, 1989; Peresani, 2008; Moroni et al., 2013; De Stefani et al., 2012).

Several tool-types are identified as part of the technocomplex: various end-scaper types, side-scapers, few burins, denticulates, retouched blades and bladelets. The geometric crescent-shaped backed piece, normally referred to as ‘lunate’ (or ‘semi-luna’ in Italian) is the fossile directeur of the industry; an innovation sometimes of microlithic dimensions (Palma di Cesnola, 1993). This tool is particularly abundant in Cavallo Cave. Lunates do not seem to originate from specific operational chains.

The high incidence of splinted pieces (‘pièces esquillées’) is another characteristic feature of the Uluzzian. Small blades and bladelets are irregular and sometimes with traces of cortex, while there is low incidence of lamellar débitage. Local raw material procurement, including thin slabs of siliceous limestone for the production of retouched pieces, is a further characteristic of the earliest Uluzzian phases (Gambassini, 1997; Riel-Salvatore and Negrino, 2009).

Based on the most complete Uluzzian complex known to date, the stratified sequence of Cavallo Cave, and the typological variability observed within it, Palma di Cesnola (1965a, b, 1989) divided the Uluzzian into three distinct industrial phases: Archaic (Cavallo layer E III), Evolved (Cavallo layers E II-I) and Final (Cavallo layers D II-D Ib). Current techno-typological and functional analyses are underway to clarify issues of origin, internal evolution, external influences and adaptations of the Uluzzian, as well as its relationship to the succeeding Aurignacian (De Stefani et al., 2012; Ranaldo, in press), broadly contemporaneous Châtelperronian and preceding Mousterian. What has become clear is that the one-to-one analogy with the Châtelperronian cannot be supported anymore as the technological details for tool production, as well as the final products and their typology, are indeed very different.

Bone industry, shell ornaments and pigments

Along with the distinct lithics and microliths, several Uluzzian sequences (Cavallo, Castelcivita, La Fabbrica) have yielded worked bone industry. About 15 bone implements in cylindrical-conical forms, mainly awls, have been discovered and described so far (Ronchitelli et al., 2009; d’Errico et al., 2012). When identifiable, these were manufactured on horse and red deer metapodials and on horse fibulae. While they incorrectly associated them with Neanderthals, d’Errico et al. (2012) suggested that the Uluzzian bone tools reveal a techno-typological complexity from their earliest appearance. In addition to these tools, a recent publication reports on the presence of bone retouchers in the Uluzzian layers of Fumane Cave (Jéquier et al., 2012).

The use and manufacture of beads is another key behavioural characteristic of the Uluzzian. Perforated marine shells have been discovered at the Uluzzian layers of Cavallo, Klissoura (and probably Cala, which is not part of the current study). They make their first appearance at the Archaic Uluzzian phase of Cavallo and increase in number, up to a few dozens, at its final phases (Palma di Cesnola, 1964, 1989). Several shell beads appear in Klissoura (n = 32; Stiner, 2010) but no ornaments have been discovered in the Uluzzian of Fumane and Castelcivita.

Beads are almost exclusively manufactured from the shells of marine molluscs, mainly scaphopods (Dentalium sp.) and gastropods (e.g., Columbella rustica, Cyclope neritea). A small number of bivalves have also been identified in the assemblages and, with the exception of a series of perforated Nuculana cf. sp. from Cavallo, the rest are not humanly modified (e.g., Pecten sp. from Castelcivita and other unidentified fragments). Just as in the Aurignacian, the Uluzzian shells are transformed into beads through perforation with the aid of lithic tools using direct or indirect percussion. In the case of the tubular Dentalium shell, the apical end is snapped off and the shell is sawn to create smaller sections.

Finally, evidence for the use of colourants (ochre and limonite pieces) has been revealed in Cavallo and Mario Bernardini caves (Borzatti von Löwenstern, 1970; Palma di Cesnola, 1989). At the moment it is not possible to tell whether these minerals were used solely for symbolic practices or other activities (e.g., hide preparation, as grinding medium or hafting agent).

Taxonomy

In terms of biological attribution, the makers of the Uluzzian have remained elusive, until very recently. The only known fossils
associated with the technocomplex are two deciduous molars from Cavallo Cave. Cavallo-B was found at a hearth at the base of the Archaic Uluzzian phase (E III), and Cavallo-C, 20 cm above, in the Evolved Uluzzian phase (E II-I). They were initially described and published by Palma di Cesnola and Messeri (1967), who classified the earliest, Cavallo-B, as modern human and Cavallo-C as Neanderthal. Churchill and Smith (2000) were unable to link the molars securely to either Neanderthals or modern humans but, unlike Palma di Cesnola and Messeri (1967), they favoured a Neanderthal attribution for Cavallo-B. This is most likely due to a mistake (reversed values) in the published dimensions these authors used in their analyses (see Benazzi et al., 2011).

Table 1

<table>
<thead>
<tr>
<th>Site</th>
<th>Lab code</th>
<th>Age ±</th>
<th>Context</th>
<th>Material</th>
<th>Reference</th>
</tr>
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<tr>
<td>Fumane Cave</td>
<td>LTL-1830A</td>
<td>29,602</td>
<td>±240</td>
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<td>LTL-1831A</td>
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<td>±350</td>
<td>A3 – str. II</td>
<td>Charcoal</td>
</tr>
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<td>LTL-1796A</td>
<td>29,361</td>
<td>±320</td>
<td>A3 – str. IV</td>
<td>Charcoal</td>
</tr>
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<td>37,828</td>
<td>±430</td>
<td>A3 – str. IV</td>
<td>Charcoal</td>
</tr>
<tr>
<td>Fumane Cave</td>
<td>OxA-8021</td>
<td>33,300</td>
<td>±400</td>
<td>A4 II</td>
<td>Charcoal</td>
</tr>
<tr>
<td>Fumane Cave</td>
<td>OxA-6462</td>
<td>33,150</td>
<td>±600</td>
<td>A4 II</td>
<td>Charcoal</td>
</tr>
<tr>
<td>Fumane Cave</td>
<td>LTL-566A</td>
<td>33,700</td>
<td>±350</td>
<td>A4 II</td>
<td>Charcoal</td>
</tr>
<tr>
<td>Fumane Cave</td>
<td>ESR</td>
<td>44 ± 7 ka</td>
<td>A4</td>
<td>Charcoal</td>
<td>Peresani et al., 2008</td>
</tr>
<tr>
<td>Castelcivita Cave</td>
<td>F-71</td>
<td>32,470</td>
<td>±650</td>
<td>rsa</td>
<td>Burnt bones</td>
</tr>
<tr>
<td>Castelcivita Cave</td>
<td>F-106</td>
<td>&gt;34,000</td>
<td>?</td>
<td>Burnt bones</td>
<td>Gambassini, 1997</td>
</tr>
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<td>Castelcivita Cave</td>
<td>F-107</td>
<td>33,220</td>
<td>±780</td>
<td>pie</td>
<td>Burnt bones</td>
</tr>
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<td>GrN-13985</td>
<td>33,300</td>
<td>±430</td>
<td></td>
<td>Charcoal</td>
</tr>
<tr>
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<td>RM-352</td>
<td>&gt;31,000</td>
<td>E II-I</td>
<td>Charcoal</td>
<td>Palma di Cesnola, 1969</td>
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<td>±1900</td>
<td>E III</td>
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<tr>
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<td>±2700</td>
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<td>Burnt bone</td>
</tr>
<tr>
<td>Cavallo Cave</td>
<td>6 AMS</td>
<td>~21–31 ka BP</td>
<td>EII</td>
<td>Burnt bone</td>
<td>Riel-Salvatore, 2007</td>
</tr>
<tr>
<td>Klissoura Cave</td>
<td>Gd-7878</td>
<td>17,430</td>
<td>±100</td>
<td>V</td>
<td>Carbonates</td>
</tr>
<tr>
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<td>Gd-12037</td>
<td>26,250</td>
<td>±310</td>
<td>V/hearth 42</td>
<td>Carbonates</td>
</tr>
<tr>
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<td>Gd-12027</td>
<td>27,100</td>
<td>±600</td>
<td>V/hearth 53</td>
<td>Carbonates</td>
</tr>
<tr>
<td>Klissoura Cave</td>
<td>Gd-10714</td>
<td>&gt;31,100</td>
<td>±300</td>
<td>V/hearth 42</td>
<td>Soil organics</td>
</tr>
<tr>
<td>Klissoura Cave</td>
<td>Gd-10715</td>
<td>&gt;30,800</td>
<td>±300</td>
<td>V/hearth 53</td>
<td>Soil organics</td>
</tr>
<tr>
<td>Klissoura Cave</td>
<td>RTT-4790</td>
<td>29,660</td>
<td>±360</td>
<td>V upper</td>
<td>Charcoal</td>
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<tr>
<td>Klissoura Cave</td>
<td>RTT-4791</td>
<td>30,774</td>
<td>±410</td>
<td>V upper</td>
<td>Charcoal</td>
</tr>
<tr>
<td>Klissoura Cave</td>
<td>Gif-99168</td>
<td>40,100</td>
<td>±740</td>
<td>V/Sq. B3/H42/175-180</td>
<td>Bone</td>
</tr>
</tbody>
</table>

With the exception of an ESR determination from Fumane, all other results are ^14C.

application of radiocarbon dating, especially towards the age limit of the technique. Some of the aforementioned Uluzzian determinations were produced on material known to be very difficult to date. For example, most measurements from Cavallo and Castelcivita were performed on burnt bones, a highly unreliable type of sample (van Strydonck et al., 2005, 2009), especially for Palaeolithic-aged material. This is because in burnt bone the measured carbon (C) comes from the mineral matrix, a highly porous and non-homogenous phase prone to external contamination. In contrast, when fresh (i.e., non-burnt) bone is dated, the measured C derives from the more resilient organic (collagen) fraction.

In addition to problems relating to dating burnt bone, many previous radiocarbon determinations for the Uluzzian were produced on charcoal/organic matter cleaned using the Acid-Base-Acid (ABA) method. This chemical protocol has been shown to underestimate systematically the age of samples older than 30 ka BP when compared with more rigorous new methods, such as the ABOx-SC protocol (Bird et al., 1999; Santos et al., 2003; Higham et al., 2009; Douka et al., 2010b; Higham, 2011; Wood et al., 2012). In turn, this means that the ABA determinations must underestimate the true age of the Uluzzian.

These methodological, 14C-related, limitations are corroborated by another fact. In at least three stratified Uluzzian sequences...
Studied sequences

Given the distinct techno-typological features and important stratigraphic position of the Uluzzian and, as of recent, its connection with the earliest modern humans in Europe, a reliable chronology is of uttermost importance in understanding aspects of the initial appearance, expansion and eventual demise of the technocomplex, which have remained unknown thus far. The reliable dating of the Uluzzian has been one of the major goals of a project initiated by the authors and performed at the Oxford Radiocarbon Accelerator Unit between 2008 and 2011. We decided to date four of the best-known Uluzzian sites (Cavallo Cave, Castelcivita Cave, Fumane Cave and Klissoura Cave 1; Fig. 1). Despite the presence of several open-air localities across Italy identified as Uluzzian on the basis of surface collections, here, priority was given to stratified sequences.

Cavallo Cave is situated on the rocky coast of the bay of Uluzzo, in Puglia, SE Italy. It was discovered in 1960 and excavations took place during 1963–1966 (Palma di Cesnola, 1963, 1964, 1965b, 1966b) and from 1986 to 2007 (Sarti et al., 1998–2000, 2002). Salvage excavations were conducted in the late 1970s and early 1980s in the process of installing a gate at the entrance of the cave to protect it from looters, who had ravaged most of the standing archaeological deposits.

The site contained a long stratigraphic succession comprising about 7 m of archaeological deposits, directly based on a marine interglacial beach conglomerate (layer O) (Romagnoli, 2012). The archaeological sequence of Cavallo (Fig. 2) is dominated by Mousterian layers (N–F I), followed by a thin layer of green volcanic ash (F2). The ash is overlain by the Uluzzian layers (E III to D Ib). These are capped by a stalagmitic floor (D Ia) and a further layer of volcanic ash (C II) altered at the top (C I). This tephra has been identified as deriving from the Campanian Ignimbrite eruption (R. Sulpizio, Personal communication). Above this are layers B II–B 1, with Late Epigravettian (Romanellian) remains, and the sequence is sealed by Neolithic layer A.

Castelcivita is situated in the Calore river valley, at the foot of the Albanini Mountains (Salerno), ~100 m above sea level. Excavations were conducted from 1975 to 1988 when a 3 m-long sequence was discovered and investigated in detail (Gambassini, 1997). The archaeological succession contained several Mousterian, Uluzzian and Protoaurignacian levels and was sealed by thick volcanic deposits with the distinctive two-phase structure of the CI (Giaccio et al., 2008). Within the stratigraphic sequence, eight human-derived phases were recognized. The three lower phases are attributed to the Mousterian and correspond to levels XIII–VII (= cgr-gar-rsi”), which contain Uluzzian remains. The Uluzzian levels are characterized by fine red sediment mixed with limestone blocks derived from the collapse of the entrance of the cave. The succeeding three phases (levels IIa-ars = rsaf-gic-ars”), contained Protoaurignacian remains within sandy sediment (see also SOM).

Fumane is a dolomitc limestone cave at the southern slope of the Venetian Pre-Alps, between the low alluvial plains and the high plateau of Mount Lessini. Systematic excavations started in 1988 and continue to this day (Bartolomei et al., 1992, Cremaschi et al., 2005; Peresani et al., 2008). The excavations have revealed a deep, 12 m thick sedimentary sequence. On the basis of distinct lithological composition, pedological features and the density and nature of cultural evidence, the stratigraphy has been divided into four main macro-units labelled S, BR, A and D (Martini et al., 2001) (Fig. 2). Layers A4–A3 from macro-unit A were recently characterized as Uluzzian (Peresani, 2008, 2012; Peresani et al., 2008; see...
with the horizon, its contents ascribed to the Uluzzian and roughly compared elements since this layer is directly overlain by the Upper Palaeolithic followed by layer VI, a mix of Upper Palaeolithic and Middle Palaeolithic contacts. A series of Middle Palaeolithic layers (XXa-g about 2.0 m thick, separated from each other by clear erosional about 6.5 m thick, and the Upper Palaeolithic-Mesolithic phase, revealed an 8 m long sedimentary succession. The cultural sequence Polished teams (Koumouzelis et al., 2001; Karkanas, 2010) that Greece. It was investigated between 1994 and 2006 by Greek and eastern edge of the Argive plain in the Peloponnese, southern also SOM). Layers A2-A1 are classiﬁed as Protoaurignacian while layers D3d, D3b and D3a are later Aurignacian units (Broglio et al., 2003). D1d has yielded a small number of Gravettian artifacts and is also SOM). Klissoura Cave 1 is a small limestone cave located at the north-eastern edge of the Argive plain in the Peloponnesse, southern Greece. It was investigated between 1994 and 2006 by Greek and Polish teams (Koumouzelis et al., 2001; Karkanas, 2010) that revealed an 8 m long sedimentary succession. The cultural sequence was divided into two broad phases: the Middle Paleolithic phase, about 6.5 m thick, and the Upper Paleolithic-Mesolithic phase, about 2.0 m thick, separated from each other by clear erosional contacts. A series of Middle Paleolithic layers (XXa–g–vii) is followed by layer VI, a mix of Upper Paleolithic and Middle Paleolithic elements since this layer is directly overlain by the Upper Paleolithic sequence in several areas. Layer V is a thin, discontinuous lensoid horizon, its contents ascribed to the Uluzzian and roughly compared with the ‘evolved’ phase of the technocomplex. It is a dark grey, clayey silty layer mainly reworked and locally in situ burnt remnants. A series of Aurignacian layers (early: IV, middle: Illig, late: Ila–c) overlaid layer V, and were followed by Gravettian à pointes à dos indifférencié or Mediterranean backed bladelets (llf’), Epigravettian (illa–d) and Mesolithic layers (3–5a) (Fig. 2) (Koumouzelis et al., 2001; Kaczanowska et al., 2010; Karkanas, 2010).

Results

New chronological framework

In the current project, 18 radiocarbon measurements were obtained for the Uluzzian layers of Cavallo, Castelcivita, Fumane and Klissoura 1 (Table 2). Shell, charcoal and bone collagen were the three types of dated material. Bones were dated only in the case of Fumane. In all other sites tested bones preserved no collagen therefore alternative material was used. All determinations were produced using the latest preparative methods (ultrafiltration for bones, ABOx-SC for charcoal, CarDS for shell), which have been described in detail by Brock et al. (2010), Douka et al. (2010a) and Wood et al. (2012). For the vast majority of samples, carbon yields and sample size were within the expected standard ranges. In the case where an unusual value was observed (variable δ13C, low %C or high C/N), these determinations got an OxA-X rather than the routine OxA- prefix (Table 2, see with notes on last two columns).

We obtained ten radiocarbon dates for Cavallo Cave, the reference Uluzzian sequence (Table 2). With one exception (Cvl 6), all determinations were produced on marine shell beads (Dentitium sp., Nuculana sp. and C. neritea), most likely used as personal or- naments. They come from the two upper phases, Evolved Uluzzian and Uluzzian sequence (Table 2). With one exception (Cvl 10), all determinations were produced using the latest preparative methods (ultrafiltration for bones, ABOx-SC for charcoal, CarDS for shell), which have been described in detail by Brock et al. (2010), Douka et al. (2010a) and Wood et al. (2012). For the vast majority of samples, carbon yields and sample size were within the expected standard ranges. In the case where an unusual value was observed (variable δ13C, low %C or high C/N), these determinations got an OxA-X rather than the routine OxA- prefix (Table 2, see with notes on last two columns).

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Most dates (OxA-19242, OxA-19256, OxA-19258, OxA-20631, OxA-19255, OxA-19254) are consistent with the stratigraphic position of the samples and range from 35 to 40 ka BP, from top to bottom. Only OxA-19257 (D II), a small, indeterminate fragment of a bivalve shell appears too old for its context (42 ka BP). It is not unusual for bivalve shells to be older than their context (see for example discussion in Sivan et al., 2005; Douka, 2011) and we suggest that this is indeed an old valve, either collected on purpose or accidentally brought to the site long after the death of the mollusc. On the other hand, OxA-21072 (and its duplicate) obtained from a C. neritea shell from D Ia, was much younger than expected considering its position in the sequence. According to the excavator, D Ib was the latest Uluzzian layer at the site. This layer was sealed by D Ib, a stalagmite crust covered by volcanic ash (C), both forming a rather continuous layer across most of the excavated area. What
makes this determination more curious is that no other archaeological material ever reported from the cave could be assigned to this time period (≈20 ka BP). We have no further details to make an informative suggestion or better explain this young determination, but we consider the shell as unrelated to the Uluzzian of Cavallo. The latter clearly ends around the time of the CI eruption when airborne tephra was deposited and covered the top of layer D.

We obtained no dates for the lowermost Archaic Uluzzian phase (E III) due to the scarcity of suitable shell for dating, the absence of bone collagen in all bones we tested, and the lack of charcoal in the stored collection. The antiquity of Archaic Uluzzian phase is, therefore, unknown but based on the corpus of the current determinations, independent stratigraphic evidence and estimations of sediment deposition rates, E III must predate E II by at least 1–3 millennia. The age of the first Uluzzian occupation at Cavallo can be determined securely through direct dating of E III or, failing that, dating of the latest Mousterian layer, which will provide a useful terminus post quem for the start of the Uluzzian at the site. Our group is currently working towards these possibilities.

At Fumane, we dated bone remains from layers A3 and A4, both assigned to the Uluzzian (possibly Archaic and Evolved, respectively). The position of the samples and their relation to structures all other cultural remains are discussed in the SOM. We have obtained five new determinations on modified (smashed and cut-marked) bone, all treated with the collagen ultrafiltration method (Higham, 2011). The ages range from 39 to 42 ka BP (Table 2). It appears that the phase in Fumane was relatively short and it is chronologically indistinguishable from the late Mousterian at the site for which several radiocarbon determinations also exist (Higham et al., 2009; Higham, 2011).

The single determination we obtained from Castelcivita comes from the uppermost Uluzzian deposits at the site (rasA, top of spit 11, square H14 I), which is normally associated with the final Uluzzian phase at Cavallo. This layer is found 50–55 cm below the well-characterized CI deposits (Giacco et al., 2008) and therefore its age should well predate the CI eruption. The layer contained evidence of hearths and the particular charcoal sample (cf. Ilex aquifolium) was dated twice, as part of experimentation with two radiocarbon pretreatment methods (ABA and ABOx-SC; Wood et al., 2012). The less-refined ABA method gave an age much younger than expected at 33 ka BP (or ≈37.0–38.8 ka cal BP), which postdates the calendar age for the eruption. Pretreatment of the same charcoal sample with ABOx-SC gave a reliable age of 36.1 ka BP (≈40.5–42.0 ka cal BP) (Table 2). This new measurement is around three millennia older than our ABA result, as well as all other determinations previously obtained for Uluzzian material from Castelcivita (Table 1). This is the first time an Uluzzian determination at the site predates the estimate age of the CI layer that seals the sequence, and agrees well with the stratigraphic position of the sample.

Just as with Cavallo, the start of the Uluzzian in Castelcivita cannot be established because there are no reliable chronometric results below rasA. Three previous determinations from the Mousterian were obtained in the 1990s (GrN-13982: 39100 ± 1300 and GrN-13984: 42,700 ± 900 from level 11/11, cr: 29–30; GrN-13983: 33800 ± 1300 from level 1/11/11, cr: 27–28) (Gambassini, 1997). These, however, were made on burnt bone and, just as with the previous young Uluzzian determinations, they should also be considered minimum ages for the Middle Palaeolithic at the site.

In Kissourea Cave, Uluzzian layer V appears locally contaminated with younger and older material at its contact with other layers (Aurignacian IV and Mousterian VI–VIII). It compares best with the later stages, Evolved or Final Uluzzian, of the Cavallo phasing. Recently, microtephra occurring as a sharp peak at the interface of layers V and IV but also spreading further up the stratigraphic column was identified as the CI (Lowe et al., 2012). This microtephra peak acts as a terminus ante quem for the deposition of the Uluzzian layer V, for which we obtained two dates on shell beads (Table 2). Both beads were reported as coming from square AA4, outside the dripline of the cave. OxA-21068 at 34.6 ± 0.2 ka BP (39.9–38.5 ka cal BP) agrees with the position of the sample beneath the CI. The fact that this date was produced on a Dentineum sp. shell is all the more important given the presence of Dentineum beads also in Italian Uluzzian contexts, such as in Cavallo Cave. The second determination, OxA-19936, obtained from a shell found 5 cm below the previous one, is much younger (≈28 ka BP). When we questioned the certainty of this level ascertainment and looked into the excavation plans it became clear that in squares AA1–AA3 (and their extension in AA4), and between 175 and 185 cm below datum, Aurignacian layer IV truncates Uluzzian layer V at places and lies in direct contact with Middle Palaeolithic layers VI and VII. Given this very young age and the rest of the determinations from overlying Aurignacian layers that centre between 33 and 30 ka BP, OxA-19936 originally assigned to layer V, is most likely to belong to layer IV or a later occupation (sub-layers Ille–g).

Bayesian framework for inter-site comparison

In an attempt to place the Uluzzian in its most likely calendar age and palaeoclimatic context, as well as assess its temporal
evolution across the dated sites, all new radiocarbon determinations were calibrated using the INTCAL09 (atmospheric and marine) curve (Reimer et al., 2009) and a Bayesian model was built using OxCal 4.1.7 (Bronk Ramsey, 2009).

The presence of the CI as a chrono-stratigraphic marker is also incorporated at the sequences where it occurs and is shown in Figs. 4 and 5. The age of the CI is taken as 39,280 ± 110 years (De Vivo et al., 2001), an age estimate that has been produced from an average of 36 40Ar/39Ar measurements from 12 proximal deposits. No macro- or micro-tephra has been identified in Fumane.

Sixteen determinations from Cavallo, Castelcivita, Fumane and Klissoura were included in the generated model (the two determination on Cvl-10 were excluded since we hold that they are not really related to the Uluzzian occupation of Cavallo). We set the resolution of the model at 20 years, and also ran an outlier detection analysis. The modelled output is shown in Fig. 4. In reality, the structure of the model consists of a few more determinations from older and younger phases, i.e., Mousterian and Aurignacian in Fumane and Klissoura, published by Higham et al. (2009), Kuhn et al. (2010) and Higham (2011). In Fig. 4 we show the relevant Uluzzian phases and determinations therein. We compare the modelling output against the NGRIP δ18O record (Andersen et al., 2006; Svensson et al., 2006) tuned with respect to the Hulu Cave U-series chronology (following Weninger and Jöris, 2008) (Fig. 4).

Overall, the modelling of the results suggests that the Uluzzian at all sites started much earlier than previously thought, at or shortly before 45 ka cal BP, and persisted for as much as 5–6 millennia, until about 39 ka cal BP. The modelled results are more precise and the newly produced chronology for the technocomplex is older and more consistent than previous estimates (compare Figs. 3 and 4).

**Discussion**

The new chronology has wider archaeological implications for our understanding of the Middle to Upper Palaeolithic transition in southern peninsular Europe (limited here to Italy and Greece). Below we discuss key points arising from this new chronological framework.

**Origins and geographic spread of the Uluzzian**

Two of the big questions surrounding the appearance of the Uluzzian are its origins and the local pathway(s) of expansion.

Given that its makers were traditionally suspected to be Neanderthals, the origins of the technocomplex were originally thought to derive from local denticulate Mousterian (e.g., Palma di Cesnola, 1993). The recent disambiguation of the biological affinities of the Cavallo teeth and their attribution to modern humans (Benazzi et al., 2011) means that an external source of origin should be sought, a wave of modern human dispersal responsible for the appearance of the Uluzzian.

The traditional east to west scenario for the spread of the Upper Palaeolithic in Europe, especially that of the Aurignacian culture (e.g., Mellars, 2004, 2006), cannot be sustained in the case of the Uluzzian because no similar technocomplexes have been discovered in the Levant or further to the east of Europe. Recently, Moroni et al. (2013) suggested that the origins of the Uluzzian should be sought in sub-Saharan Africa on the basis of distinct technotypological similarities of the Uluzzian with assemblages belonging to the Middle Stone Age to Late Stone Age transition. These authors also suggested that the Uluzzian spread in southern Europe via an Adriatic coastal route (Moroni et al., 2013). The fact that both the Adriatic and the Peloponnese are part of this geographic spread may relate to the emergence of coastal areas of the Ionian-Adriatic during glacial periods, which could have made such a dispersal route available. Ferentinos et al. (2012) discuss the possibility of seafaring around western insular Greece during the Late Pleistocene. The authors suggest that hominids (both Neanderthals and early modern humans) were capable of seafaring activities, possibly encouraged by favourable regional coastal configuration during the Middle and Upper Palaeolithic. Unfortunately, the absence of reported Uluzzian sites outside the restricted circumference of Italy and southern Greece and in the intermediate regions between Africa and southern Europe, as well as the inundation of large tracks of land in the Adriatic and other coastlines during the Holocene, render the East Africa-to-southern Europe a hypothesis only based on techno-typological affinities of the lithic toolkit and other elements of the archaeological record (production of beads, use of colourants, modern human affinities). Only the excavation of additional sites and the identification and study of further Uluzzian assemblages within and outside the technocomplexes current geographical span will elucidate exact dispersal pathways and areas of Uluzzian influence.

Even within the limited geographic area of Italy, where the majority of the archaeological evidence stems from, the debate on whether the Uluzzian first appeared in the south, centre (Palma di Cesnola, 2004; Ronchitelli et al., 2009) or the north (Perey, 2008) of the peninsula remains open. Scenarios of delayed colonisation of the south by northern Uluzzians (e.g., Kaczanowska et al., 2010) have been recently put forward. Here, we attempted to use our new data to answer this question. Ordering of the probability distribution functions (PDFs) that were generated by the Bayesian

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**Figure 5.** Probability distribution functions (PDFs) for the start and end boundaries of the Uluzzian at the studied sites, as well as for the start of the Proto-Aurignacian at the Italian sites mentioned in the text. These were generated after modelling the new radiocarbon determinations, shown in Fig. 4, using the OxCal platform (Bronk Ramsey, 2009). The start of the Uluzzian in Cavallo is given here as the PDF for the start boundary of the Areachic Uluzzian (E III). On the top of the graph, the NGRIP δ18O record is shown in blue (Andersen et al., 2006; Svensson et al., 2006) and the Greenland Interstadials, corresponding to ameliorated climatic conditions, are numbered. The age for the CI ash is shown on the top of the sequence as a grey line at the sites it occurs, and as dashed line in Fumane where its presence in not confirmed.
model for the start of the Uluzzian phases at each site (Fig. 5) allows us to estimate the chances for an Uluzzian layer at a site being older than that at another site (Table 3). In the absence of independent stratigraphic markers to confidently identify one context as being contemporaneous, younger or older than another, we require a start boundary to have significantly more chances of being earlier than another start boundary. The results of this ordering exercise suggest that the generated age estimate for the start of the Uluzzian in the Italian south, represented by Cavallo, appears to be older (70% chances) than that of Fumane in the north of Italy. However, this should be seen only as a tentative hypothesis given that the lowermost Uluzzian levels and final Mousterian levels at Cavallo (and Castelcivita) remain undated and unconstrained in absolute terms, while those of Fumane are. Improved chronology might change the picture. With regards to the other sites, the Uluzzian in Klissoura remains the youngest of all.

Based on the current data, the only valid conclusion one can reach is that the Uluzzian is already present both in southern and northern Italy by 39–40 ka BP (43–46 ka cal BP). How much earlier before that, is not known. The evidence from Greece is limited so far and appears rather late. It is expected that comprehensive dating of more existing sites will help to answer questions revolving around the origins of the Uluzzian technocomplex.

From a climatic point of view, the appearance of the Uluzzian as we currently define it, falls at the end of Greenland Interstadial 12 (GIS 12) and the cold stadial between GIS 12 and 11. While Cavallo E III lacks direct determinations, the Bayesian model tentatively places its age well within GIS 12. GIS 12 follows immediately after Heinrich Event 5 (HE5), a climatic low at ~48 ka. Müller et al. (2011) have suggested, on the basis of environmental proxies, that the initial arrival of anatomically modern humans is very likely to have occurred post-HE5 and during GIS 12. The independent new evidence from the Uluzzian sites in our study seems to agree with this suggestion. The decrease in temperature inferred from the composition of the faunal assemblage in Cavallo layer E III (Boscato and Crezzeni, 2011) and at levels A4 and A3 in Fumane (Tagliacozzo et al., 2013) may therefore correspond either to the onset of HE5 or the stadial conditions between GIS 12 and 11. If the latter is correct the start of the Uluzzian would slightly postdate GIS 12.

The Uluzzian and its relationship to the Aurignacian in Italy

In southern Italy, Castelcivita (and Cala, not examined in this study) is a crucial archaeological sequence because the Uluzzian is directly followed by a series of Aurignacian layers. Although these Aurignacian layers are currently undated, their age is constrained by two ‘known-age’ horizons: the uppermost Uluzzian layer rs“ dated here between 40.6 and 41.9 ka cal BP (Table 2) and the CI volcanic debris of estimated calendar age around ~39.3 ka. This suggests that the Aurignacian in Castelcivita arrived soon after 41–42 ka and advanced in two successive forms: initially as Protoaurignacian with Dufour bladelets, and later as a local variant incorporating tiny ‘Castelcivita micropoints’ (Gambassini, 1997). The Aurignacian lasted at the site for the next ~2–3 millennia when the sequence was completely sealed by the pumices and grey ash of the CI eruption (Giacco et al., 2008). At a nearby open-air site, Serino (Fig. 1), the CI covers Aurignacian deposits with rare micropoints similar to those of Castelcivita’s Protoaurignacian (Accorsi et al., 1979). Recently, four charcoal samples from a distinct hearth in Serino were dated using ABOx-SC at ~34.5 ka BP (Wood et al., 2012). When calibrated, these determinations correspond exactly to the accepted calendar age of the CI eruption at 39.3 ka (De Vivo et al., 2001). Based on these two archaeological sequences, we can suggest that Protoaurignacian groups had spread into western and central Campania by 39 ka and even earlier, but not before 41–42 ka.

Moving to northern Italy, the Aurignacian has been securely dated in two sites: Fumane in Verona and Mochi in western Liguria. The Uluzzian in Fumane seems to have ended shortly after 42 ka cal BP, and there seems that occupation of the site came to a halt for about a millennium, and possibly more, until the arrival of the first Aurignacians. The Aurignacian chronology for Fumane was described by Higham et al. (2009) and Higham (2011) who, on the basis of new determinations for ABOx-treated charcoal and ultra-filtered bone collagen, placed the earliest Protoaurignacian layer A2 at 40.5–41.2 ka cal BP. This mirrors very well the estimated age for the spread of the Protoaurignacian in Castelcivita. Unlike Castelcivita, where occupation terminates with the CI eruption, Fumane is visited by Aurignacians until about 36–38 ka cal BP as evidenced by the cluster of dates at around that time (Higham et al., 2009; Higham, 2011).

In Riparo Mochi (Fig. 1), evidence for older Aurignacian presence was reported by Douka et al. (2012). A series of 15 radiocarbon dates, obtained mainly on shell beads and one charcoal sample, were used to date the largest part of the stratigraphic sequence. No Uluzzian is found at the site, and a semi-sterile layer, currently under study, follows the final Mousterian layer. The new radiocarbon determinations place the start of the Protoaurignacian occupation at the site (layer C) at about 37 ka BP or between ~42.7 and 41.6 ka cal BP. Layer C of Riparo Mochi is therefore the oldest,

Table 3

<table>
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<th>Probability</th>
<th>ULUZZIAN</th>
<th>AURIGNACIAN</th>
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<td></td>
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The pdfs corresponding to this ordering are shown in Fig. 5.
directly-dated Aurignacian assemblage in Italy. A second group of younger dates relates to an Early Aurignacian facies at around 32 ka BP or between 37.3 and 36.4 ka cal BP (Douka et al., 2012). The synchronous shell and charcoal radiocarbon determinations from Riparo Mochi suggest strongly the reliability of marine gastropods as an appropriate substrate for 14C dating, and dismiss large variations of the local marine reservoir during the period at issue (contra Banks et al., 2013).

All other Protoaurignacian or Early Aurignacian industries in Italy either lack secure absolute determinations or have been shown to be younger by several hundreds to a few thousand years (e.g., Bombrini, Paglicci, Fumane).

There is a clear chronological and stratigraphic separation between Aurignacian and Uluzzian assemblages at the sites where the two co-occur. At no site is there evidence of interstratification between the two technocomplexes and only the presence of some ‘aурignacoid’ tools in the final phase of the Uluzzian offers limited support that the two populations (Uluzzian and Proto- or Aurignacian groups) could have met. However, on the basis of the observed spatio-temporal distinction we observe on our results we may suggest that the transition from the Uluzzian to the Aurignacian could have its roots in a secondary modern human population movement which ultimately spread across Europe. The processes involved in this succession, whether those of population replacement, elimination or incorporation/absorption, remain unknown.

With regards to the advance of the Aurignacian, and therefore its relationship to the final Uluzzian in the studied regions, the older determinations from Mochi and the well-established connections of its Protoaurignacian inhabitants with both Italy and France, may hint at a northwest, possibly to northeast, and finally southern Aurignacian spread (i.e., from southern France to northern Italy and finally to southern Italy), from ~37 ka BP (~42.5 ka cal BP) onwards. Although there is little evidence from intermediate regions, this hypothesis corroborates the later ages that exist for the Aurignacian in southern Italy (Paglicci, Serino, Castelcivita, Cala), where the industry does not appear before ~35 ka BP (39–40 ka cal BP).

The very small number of excavated and dated Aurignacian sites in Greece does not permit a broad discussion on the chronological position of the technocomplex, neither on its origins. Similarly to the Italian South, a relatively late arrival for the Aurignacian may be suggested, since nowhere does the technocomplex predate 35 ka BP (e.g., Franchthi, Klissoura) (Kuhn et al., 2010; Douka et al., 2011). In terms of origins, a northern (Balkan) route is the most prevalent model, however, western/north-western influences from across the Adriatic cannot be excluded either.

**Scenarios for co-existence between Uluzzians (modern humans) and late Mousterians (Neanderthals)**

We wanted to investigate how the older age estimates for the appearance of the Uluzzian in Italy and Greece may influence contact scenarios between modern humans and Neanderthals. Reviews on the topic of Neanderthal and modern human contact have focused almost exclusively on spatio-temporal overlap to verify or negate population contacts. Long periods of regional co-existence are bound to facilitate population contacts. This, in turn, would give rise to uni-bidirectional flow of knowledge (acculturation) and/or of genetic material (interbreeding) leading to the development of industries possibly with both Middle Paleolithic and Upper Paleolithic characteristics, as well as hybridized human forms. One of the main points of refuting acculturation scenarios between Neanderthals and early modern humans has been the claim that there was no significant period of coexistence between the two populations (e.g., Zilhão et al., 2008).

It is now thought that Neanderthals may have survived in wider Europe until about 40 ka (e.g., Pinhasi et al., 2011), several millennia after the appearance of the Uluzzians in Italy and Greece, placed at ~ 43–45 ka. The claim of insufficient time for co-existence/acculturation therefore can no longer be sustained without further examination of the record for Neanderthal presence synchronous to the Uluzzian occupation of southern Europe.

Sadly, both in Italy and Greece final/terminal Mousterian contexts, thought to represent the latest Neanderthal populations, are very badly dated. In Italy, only Mochi and Bombrini in Liguria (~36–38 ka BP/41–43 ka cal BP) (Douka et al., 2012), Fumane Cave (41–42 ka BP/44–46 ka cal BP) (Higham et al., 2009) and, less securely, Mezzena rockshelter (35 ka BP/~40 ka cal BP) (Longo et al., 2012) have been dated using the latest preparative methods. In the case of Mezzena rockshelter, claims for late Neanderthal survival were made on the basis of a single 14C measurement on mammal bone. However, a single measurement cannot provide the precision required for drawing strong conclusions and more extensive work is needed. In all other instances (Broion, S. Bernardino, Rio Secco, all Onda, Buca della Iena, Breuil, Sant’Agostino, Reali, Castelivicina, Poggio shelter, Oscurucuisto) (Hedges et al., 1994; Gambassini, 1997; Caramia and Gambassini, 2006; Milliken, 2007; Peresani and Gurioli, 2007; Riel-Salvatore, 2007; Boscardo et al., 2009; Ronchitelli et al., 2009; Peresani, 2011; Peretto, 2012), Mousterian determinations should be considered at best minimum ages.

In Greece, the situation is worse since the record is patchy and discontinuous, and only a handful of poorly-dated sites have been assigned to the Middle Palaeolithic period (Fig. 1). Mousterian sites with absolute ages include Theopetra, dated to the last Interglacial or before (end of OIS 6/beginning OIS 5; Valladas et al., 2007), Asprochaliko imprecisely dated at ~40 ka BP (Bailey et al., 1992), and Kalamakia at >40 ka (Darlas, 2007). Some later ages for find-spots close to River Peneios, between 28 and 44 ka BP (32–48 ka cal BP), have been attributed to a late persistence of Neanderthals in the area (Harvati et al., 2009). Caution is advised, however, since determinations of such antiquity, produced using conventional radiocarbon methods and less refined chemical pretreatment protocols, must represent minimum ages at best. Klissoura 1 and Lalokis I both contain final Mousterian assemblages and they are currently the best-dated sites for this period in Greece. In Lalokis, late Middle Palaeolithic Unit Ib was dated between 39 and 43 ka BP (43–48 ka cal BP) (Panagopoulos et al., 2004; Elefant i et al., 2008), although none of the determinations were treated with modern preparation methods for charcoal (ABox) and therefore may also correspond to minimum ages. At the same site, a ‘transitional’/initial Upper Palaeolithic (IUP) complex with evidence of Upper Palaeolithic tool types (Unit Ia) is associated with statistically identical determinations (38–42 ka BP/42–48 ka cal BP). The excavators have suggested that the industry of Unit Ia was the product of Neanderthals on the basis of a Neanderthal tooth found there (Harvati et al., 2003). The determinations from Unit Ia predate the Uluzzian evidence of Klissoura and there appears no obvious connection between the IUP of Lalokis with the Uluzzian of Klissoura in terms of material culture or lithic techno-typology.

Finally in Klissoura, some recently obtained radiocarbon determinations place the end of the Mousterian at about 41–40 ka BP (AA-73819: 40920 ± 580, AA-73818: 41480 ± 810; Kuhn et al., 2010) or at ~44–45 ka cal BP. Further down that stratigraphy, layer VII is dated with one measurement (AA-73820: 4900 ± 1770 BP) at ~47–51 ka cal BP. A chronological gap of several millennia is identified in the determinations available for the terminal Mousterian and the Uluzzian in Klissoura, which corresponds well with the stratigraphic discontinuities observed at the interface of Middle Palaeolithic layers VII–VI and the Uluzzian.
layer V. Again, Klissoura refutes scenarios of population overlap in the Peloponnesian. We conclude that no evidence to support modern human and Neanderthal co-existence/interaction can be found in Greece. Overall, at all sites where a succession of Mousterian-Uluzzian Aurignacian occupations exists, this always follows the indicated sequence with no interstratifications. In addition, at most sites (including the sequences studied here (Cavalo, Castelcivita, Klissoura)) the Mousterian is separated from the Uluzzian by a sedimentary break, a layer of volcanic ash or other stratigraphic hiatus, which may suggest that a period of time has elapsed between the two phases.

Taken together, while the antiquity of modern human presence in southern peninsular Europe (Italy and Greece) has been extended significantly with the attribution of the Uluzzian to modern populations, neither the available chronology nor the stratigraphic evidence of late Mousterian contexts may validate parallel existence and overlap between late Neanderthals and early modern humans in the region concerned (contra Longo et al., 2012; Zilhão, 2013). In turn, this may lead us to suggest that the Uluzzians arrived at ‘virgin lands’ where Neanderthal numbers were very low, if at all present. This is in agreement with the hypothesis expressed by Moroni et al. (2013).

A further implication of this scenario, which (i) identifies the Uluzzian as a product of modern humans, and (ii) allows its development far from and independently of Neanderthal influences, is the potential support it offers to the suggestion that other transitional industries reported from Europe and the Levant may indeed be the product of modern humans and not Neanderthals (Bar-Yosef and Bordes, 2010; Bordes and Teyssandier, 2011; Douka et al., 2013). We need, however, to remain cautious and suggest that further detailed work is required if we were to understand aspects of other transitional technocomplexes exhibiting similar characteristics to the Uluzzian, such as the Balkan Bachokrian (e.g., level 11 of the Bacho Kiro) or the Bohunician (or Emiro-Bohunician) of Central Europe. A good start would be a fresh and reliable absolute dating of these contexts.

Conclusions

We present here the first integrated chronological synthesis for the Uluzzian, currently assumed to be the oldest modern human technocomplex in Europe. By using a series of new radiocarbon determinations on shell, bone and charcoal substrate, all produced with the latest preparative methods at the Oxford Radiocarbon laboratory, and a purpose-built Bayesian statistical framework, we constrained the age of the Uluzzian and compared it with that for previous and succeeding technocomplexes (Mousterian, Aurignacian). We conclude that the Uluzzian arrived in Italy and Greece, where its only occurrences are identified so far, shortly before 45 ka and continued evolving until its final stages — 39 ka. Issues of origin are not easy to disentangle at the moment, but similarities of the Uluzzian tool techno-typology with assemblages in East Africa have been drawn. Yet, given the lack of intermediate assemblages between Africa and southern Europe, as well as the absence of the Uluzzian outside the limited geographical circumference of Italy and Greece, any quest for roots will remain challenging.

Regardless of where the Uluzzians arrived from, in addition to modern human anatomy they also convey fully-modern behaviour expressed through techno-typologically complex lithic toolkits, highly-adaptive subsistence strategies, bone tool industry, use of pigments and productions of ornaments. These are part of the ‘Uluzzian package’ since its earliest appearance in southeastern Europe and many of these features, such as bone tools and shell beads, do not belong to the behavioural package of previous populations (Neanderthals) living in the same region. The secure chronology presented here for the Uluzzian elucidates the least-known aspect of the technocomplex and attempts to place the arrival of early modern humans in Europe at the right period. This we hope will enable convincing future comparisons of the Uluzzian technocomplex with other transitional and early Upper Palaeolithic industries in wider Eurasia.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jhevol.2013.12.007.

References


