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Laboratory Excavation of a Neolithic Grave from Avignon-La Balance-Ilot P (France): Burial Practices and Garment Reconstruction

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ABSTRACT
The grave of La Balance-Ilot P, in Avignon, southern France, is an individual and isolated burial, attributed in the 1970's to the Mesolithic or the Early Neolithic. The grave, partially unearthed, was exhibited and stored at the Calvet Museum until its rediscovery and laboratory excavation in 2009. We used 3D laser recording and field anthropological methods, followed by a multidisciplinary approach. The deceased, an adult male, was buried in primary deposition without any architectural features preserved. For the first time in the Mediterranean early Neolithic, this study led to the identification of a garment adorned with sophisticated embroidery using 158 red-colored *Columbella rustica* shells and 16 red deer canines. Calibrated AMS dates allow us to reliably place it in the early 5th millennium B.C. reinforcing evidence for long distance intercultural relationships in Europe during the Neolithic.

KEYWORDS
Archaeothanatology; ornaments; northwestern Mediterranean; 3D laser recording

Introduction

The Neolithic way of life, coming from the Near East, was spread across the northwestern Mediterranean by the first farmers of the Impresso-cardial (IC) complex in the 6th and early 5th millennia B.C. This region was partially occupied by the last hunter-gatherers of the Mesolithic (7th and first half of the 6th millenia B.C.) whose role in the Neolithization process remains highly debated (e.g., Binder 2013; Rigaud 2011; Rigaud et al. 2015). Although reliable data on the economic and technical aspects of both societies have increased, their funerary ideologies are still poorly understood. The discovery of burial structures within these contexts remains rare, especially in southern France. The characterization of their funerary practices is thus of particular importance (Meiklejohn et al. 2010; Zemour 2011, 2013). Therefore, the complete analysis of the burial of Avignon-La Balance-Ilot P (henceforth, ABIP) (FIGURE 1), previously attributed to either the Mesolithic or Cardial Neolithic on the basis of its isolated situation, the folded position of the deceased, the presence of ochre, and perforated *Columbella rustica* shells, was an important challenge. The chronological uncertainty was also a major issue for refining the inventory of early Holocene burial structures.

In 1974, a rescue excavation was conducted by S. Gagnière at ABIP, in a district in Avignon (Vaucluse, France). While this excavation concerned historical structures, an individual burial was discovered in the bare earth floor of a Roman or Medieval house. After a superficial excavation, the grave was removed as a whole and surrounded by a wooden cast (Courtin 1974; Sauzade 1983) (FIGURE 2). Initially exhibited at the Calvet Museum, it was stored there until 2009, when its complete laboratory excavation was performed. Our aims were to reveal and to interpret the treatment of the deceased and to establish the cultural attribution of this exceptional discovery characterized by an abundance of ornaments unknown in Mesolithic or Early Neolithic contexts in the northwestern Mediterranean. To this end, a multidisciplinary approach was undertaken, including 3D laser-scanner recording and the taphonomic analysis of the burial. Isotopes and direct AMS dates were obtained on human bone collagen, whereas zooarchaeological and techno-functional analyses were performed on ornaments. Coloring matter was subjected to physicochemical analyses. Below we present the complete reassessment of this grave and address new questions regarding cultural traditions during the early 5th millennium B.C.

Lab Excavation Methods and Recording Techniques

As the initial orientation of the deposit was not specified in the field notes, a local 3D reference system was created in order to establish accurately the respective orientation and location of each skeletal element. The side of the wooden cast closest to the cervical vertebra was considered as facing north. The skeleton and associated beads were excavated following field anthropological methods (Duday 2009). During the process, an exhaustive set of photographs was taken: of the individual details of each anatomical region, of anatomical connections, and of the beads and their connection with the skeleton. Digital photographs were printed and used during the removal of the skeleton. Each object was outlined, numbered, and identified on a record sheet, including its location and orientation (side, direction, etc.).

Laser-scanner survey using a FARO Focus device was run before and after each *décapage* (cleaning) along with manual

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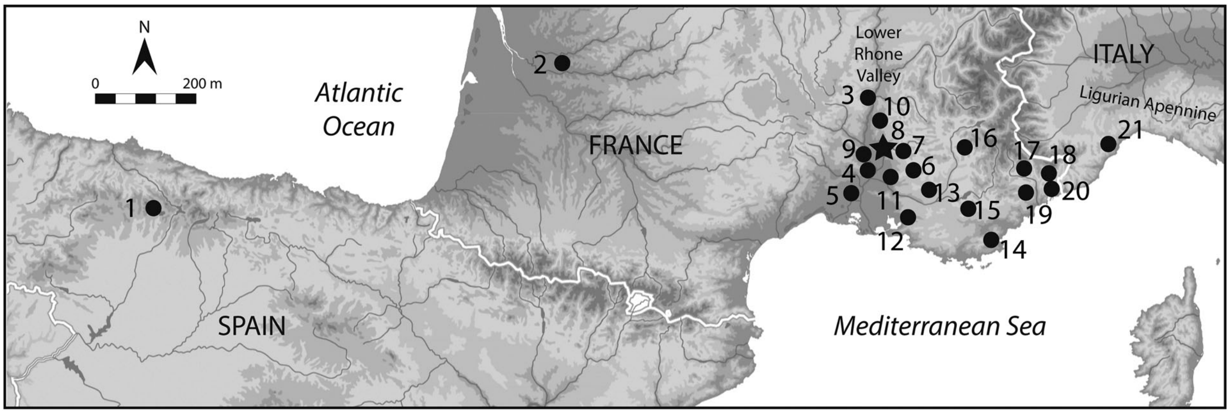

Figure 1. Locations of archaeological sites mentioned in the text. 1) Valdelugueros–La Braña (cave); 2) Saint-Germain-la-Rivière (rockshelter); 3) Malataverne–Aven des Iboussières (sinkhole); 4) Remoulins–Taï (cave); 5) Nîmes–Mas de Vignoles X; 6) Vidauque–Cheval Blanc; 7) Malemort-du-Comtat–Unang (caves); 8) Avignon–La Balance Ilot P; 9) Courthézon–Baratin; 10) Lamotte-du-Rhône–Petites Bâties; 11) Venasque–Céron; 12) Châteauneuf-les-Martigues–Font-des-Pigeons (rockshelter); 13) Jouques–Adaouste (cave); 14) Cavalaire–Centre-Ville; 15) Salernes–Fontbrégoua (cave); 16) Peipin–Frigouras; 17) Saint-Benoit–Lare 2 (cave); 18) Castellar–Pendimoun (rockshelter); 19) Peillon–Rastel; 20) Nice–Giribaldi (rockshelter); 21) Finale–Aquila, Arene Candide, Pian del Ciliegio and Pollera (caves) (Background map: Géoatlas and A. Zemour).

recording in order to compare both procedures. Landmark spheres were placed around the skeleton to allow the automatic assembly of the different laser-scanner surveys with FaroScene software (FIGURE 3A). This allowed an optimal replica in the form of a complete cloud of spots with a 2 mm accuracy (FIGURE 3B). The clouds of colored spots available for each décapage were combined and referenced in the relative coordinate system. To obtain an overview restricted to the individual and his adornment, excluding the sediments, each bone and artifact was outlined. The resulting virtual model allowed a direct and 3D view of the ornaments in association with the skeleton (FIGURES 3B, 4). It provided an analytical support and a database, including an active link to the photographs as well as descriptive and contextual information (FIGURE 3C). The virtual model was not only useful in archiving and replicating the different stages of the excavation; by refining and multiplying the views, it also offered a new scientific analytical approach. For example, during manual recording, even though viewpoints and frames were multiplied, a flattening of volumes could not be avoided whereas the 3D model perfectly reconstructed them.

Analytical Methods

Biological analyses

The age at death of the individual was estimated using the iliac sacro-pelvic surface (Schmitt 2005). The sex diagnosis was based on the measurements of the coxal bone (using the DSP method) (Murail et al. 2005) and the stature was determined following Cleuvenot and Houët's (1993) tables. Aftereffects of pathologies that may have left permanent marks on the skeleton were sought through a macroscopic examination of the bones. No lesions were detected. The analysis of ABIP human remains allowed the acquisition of new stable isotope data to address both the preservation of

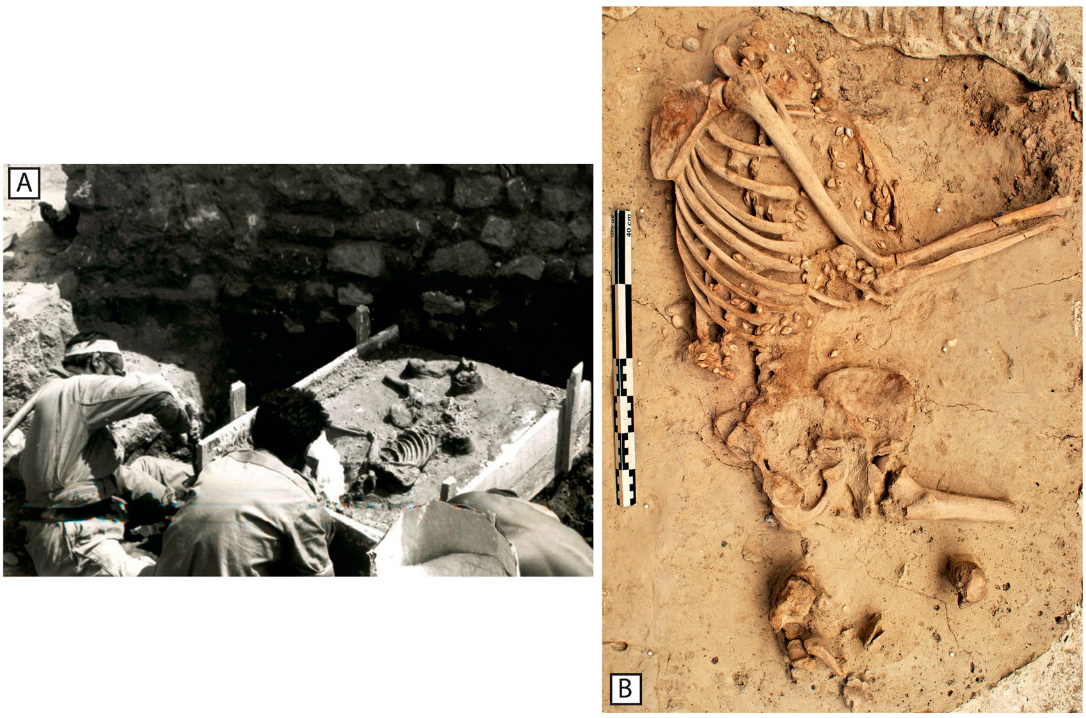

Figure 2. A) Removal of the ABIP grave in 1974 (© SRA PACA); B) Overhead view of the grave after its first *décapage* (cleaning) in 2009 (photographed by A. Zemour).

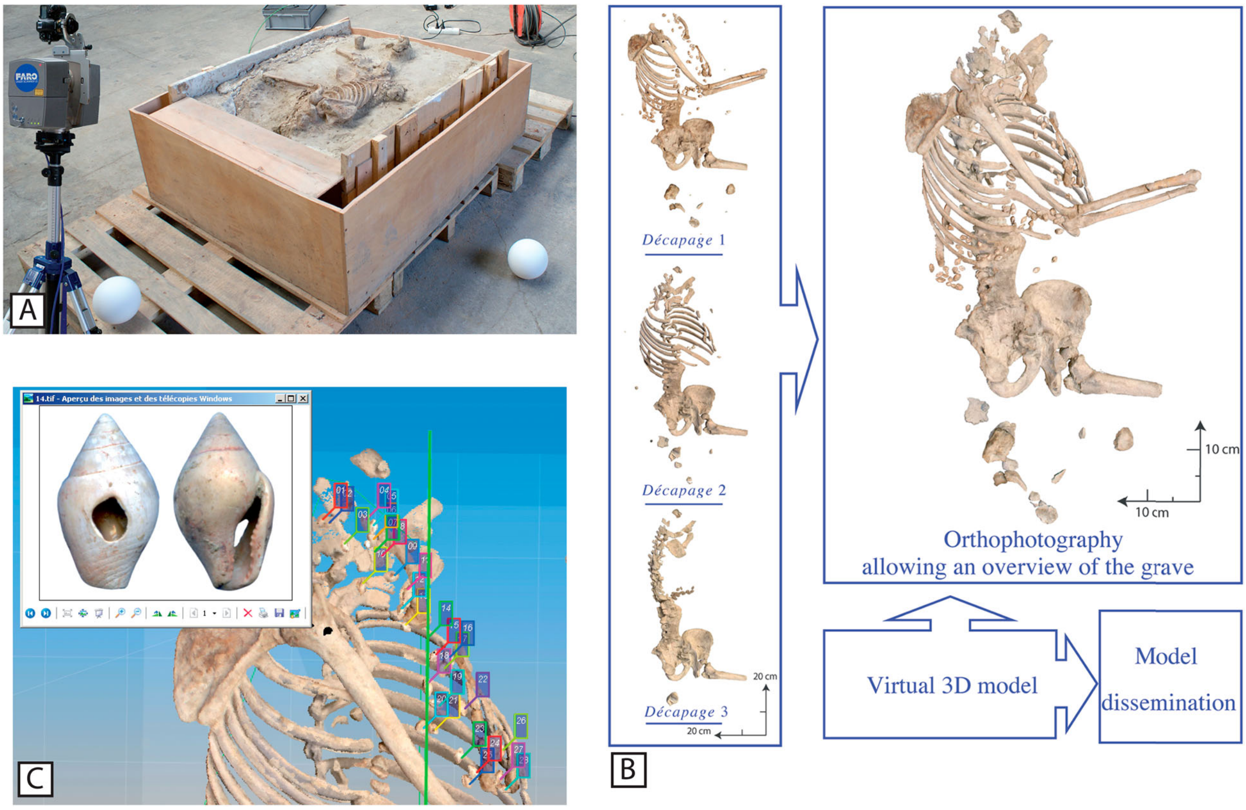

Figure 3. A) View of the grave with the laser-scanner and the landmark spheres (photographed by A. Zemour); B) Creation of the 3D model (created by S. Sorin); C) The database linked with the 3D model (created by S. Sorin).

material for radiocarbon dating and dietary practices in a Mediterranean environment.

Collagen was extracted from a rib fragment (< 1 g), following Longin (1971) and Bocherens (1992). Spongious (cancellous) bone was removed and only clean cortical bone was used. Freeze-dried collagen was analyzed by EA-IRMS (Iso-Analytical Ltd., Crewe, U.K.) to obtain its elemental composition and stable isotope ratios. Collagen extracted met all preservation criteria with an extraction yield of 19.4 mg/g, and carbon and nitrogen content of 45.1% and 14.4% respectively (Ambrose 1993; van Klinken 1999) and a C/N atomic ratio (3.6) within the accepted range (De Niro 1985).

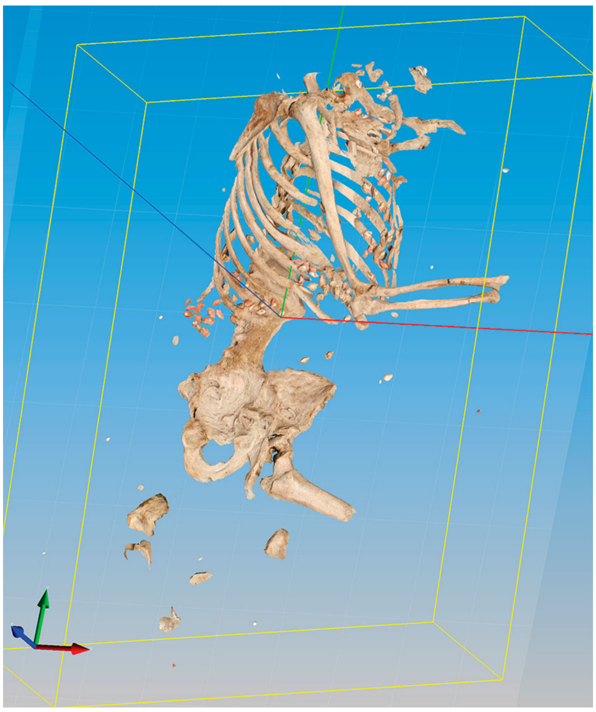

Figure 4. 3D model of the ABIP human skeleton and associated adornments from the ABIP grave (created by S. Sorin).

AMS dates

As the δ^{13}C and δ^{15}N values obtained after analysis of the human bone collagen did not indicate any reservoir effect due to marine or lacustrine food consumption, two extracts of the original sample were dated using the AMS facilities of CEDAD (Università del Salento, Lecce, Italy). Duplicating the datings from a single sample allowed discussion of the reliability of the results or the detection of any post-depositional problems. In addition, duplication provided a good opportunity to run combined probabilities in order to gain accuracy. Radiocarbon dates were calibrated using OxCal v.4.2 (Bronk Ramsey and Lee 2013).

Taphonomy

The analysis of the grave combined the reconstruction of the burial process with taphonomic factors, with the intention to restore the grave's original configuration (Duday et al. 1990). The discussion was structured around anatomical relationships by observing the presence or absence of bones, the spatial position of each bone and their relative positions as well as those of other remains (e.g., Ubelaker 1997; Roksandic 2002; Duday 2009). The taphonomic analysis thus required a multitude of highly precise spatial data. The 3D model with its millimeter resolution offered a major improvement in the analysis of the distribution of the bones and ornaments as well as their relationships to each other. The microtopography provided by the 3D model facilitated the identification of anatomical connections and disarticulations of the bones situated outside the initial volume of decomposition, but also movements inside it (FIGURE 4).

Ornaments

The whole bead assemblage is composed of 158 perforated shells from marine gastropods (*Columbella rustica*) and 16 perforated red deer upper canines (*Cervus elaphus*) (FIGURE 5). In order to obtain information about the choice and procurement of these hard animal materials, taphonomic, zooarchaeological, and morphometrical data were collected with reference to several studies from European prehistoric contexts (e.g., Driscoll and Weltin 1973; D'Errico 1993; Taborin 1993; D'Errico and Vanhaeren 2000; Stiner 2003; Bonnardin 2007, 2009; Vanhaeren 2010; Rigaud 2011; Cristiani and Boric 2012). Regarding the red deer canines, biological data were compared with other prehistoric Mediterranean populations such as those from the sites of Aven des Iboussières (D'Errico and Vanhaeren 2000), Saint-Germain-la-Rivière (Vanhaeren and D'Errico 2003) and La Braña (Rigaud et al. 2010).

The reconstruction of the bead manufacturing process was based on the analysis of the technological traces, their dimensions (maximum lengths, widths of complete or fragmented artifacts, diameters or maximum lengths of the perforations) and the locations of the perforations (Taborin 1993; Bonnardin 2009; Vanhaeren 2010; Rigaud 2011). Use-wear patterns were studied to determine the use including the fastening system. Combined with the 3D model and the taphonomic analysis, these results helped us to determine the original arrangement of the ornaments in relation to each other and with the deceased. The material was examined at magnifications from 7.5 to 50 using a stereomicroscope Olympus LZH with optical fibers lighting and a Leica DFC295 digital color camera.

Coloring matter analysis

Traces of red coloring matter were visible on bones, on ornaments, and in the sediments. Twenty-three samples were analyzed (one limb bone fragment; 20 *Columbella rustica* shells and their impressions in the sediments as well as two colored sediment samples) in order to characterize their precise locations and nature, their transformation processes, their places within the assemblage and, finally, their place in the burial practices.

In order to identify the composition of the coloring matter, elemental analysis by micro-X ray fluorescence (µXRF, ARTAX/BRUKER, Rh X-ray tube, 50 Kv-800 µA, spot size 600 µm) was run on three shells, one sample of colored sediment and two samples of colored soil impressions. Structural phases were identified by X-ray powder diffraction (p-XRD, Bruker D8 Focus, Co, 40mA-35Kv, LynxEye detector, step size 0.02° per second) on micro-samples of shells, soil and bone samples. Six shells were studied by scanning electron microscopy (SEM, Philips XL30 LaB6 ESEM, Low Vacuum mode, 0.5 mbar pressure, 20 kV, work distance 10 mm, back-scattered electron imaging). The elemental composition of each component was characterized by energy dispersive spectroscopy (SEM-EDS, Oxford, SiLi, working distance 10 mm).

Results

The skeleton

Bones are well preserved but some parts of the skeleton were lacking and several bones were partially destroyed (FIGURES 2, 4). According to G. Sauzade (1983), this is due to the fact that parts of the lower limbs were severed during the construction of a recent wall, and the skull was taken off or destroyed by the digging of a pit during the Middle Ages. Moreover, parts of the left forearm were found at the bottom of the pit. No artificial modification was found on the cortical bone surfaces. Red coloring matter is unequally present on the bones' surfaces. According to the iliac sacro-pelvic surface conditions, the ABIP individual died between 20 and 49 years of age. DSP results show a higher probability that this individual was a man (PM: 0.9946) rather than a woman (PF: 0.0054). Only the left humerus was complete enough to be measured. According to its length (318 mm), the stature of the individual would have been around 167 cm.

AMS dating

The close collagen sample dating results (TABLE 1) allowed the running of a combination using the OxCal R_Combine function of the dates with quite a good confidence interval (χ^2-test run by OxCal: df = 1, T = 2.0 [5% 3.8]). The most probable ages of the skeleton range between ca. 4950 and 4800 B.C. (2σ), i.e., the Early–Middle Neolithic transition.

Palaeodietary data

Stable isotope data (TABLE 2) were compared along with those from the human (G.H-4.5-10 burial) and faunal remains found at Malemort-du-Comtat-Unang (Goude 2007), which is the closest site in time and space to ABIP (FIGURE 1) (TABLE 2). Moreover, animal stable isotope ratios offered an indispensable local isotopic baseline to interpret human data in this environment. Carbon and nitrogen stable isotope ratios at ABIP are in agreement with other human data recorded in Mediterranean France for the Neolithic period (Goude 2007). Δ^{13}C human value from ABIP is consistent with data recorded for animal remains from Unang which supports food supply in the local environment. Δ^{15}N value is 4.6‰ higher than the δ^{15}N average of domestic herbivores and 7.2 ‰ higher than δ^{15}N average of wild animals (i.e., 5.7‰, higher than the fauna as a whole). The position of ABIP in the local trophic web supports the hypothesis of important animal protein consumption (FIGURE 6). This result is similar for the female at Unang (δ ^{15}N human-animals = 4.5‰) and also for most of the individuals dated to the Early Neolithic in southeastern France (Goude 2007). As for the other humans considered, the high position in the trophic web of the ABIP individual cannot be explained by marine protein intake, despite the proximity to the sea, as δ^{13}C is consistent with the consumption of terrestrial resources. The consumption of freshwater fish and/or young animals (not weaned) could lead to similar results but no zooarchaeological data support this hypothesis. In the current state of research, it seems that terrestrial herbivores (domestic and wild) played an important role in human diet at this time (Le Bras-Goude 2008; Rowley-Conwy et al. 2013).

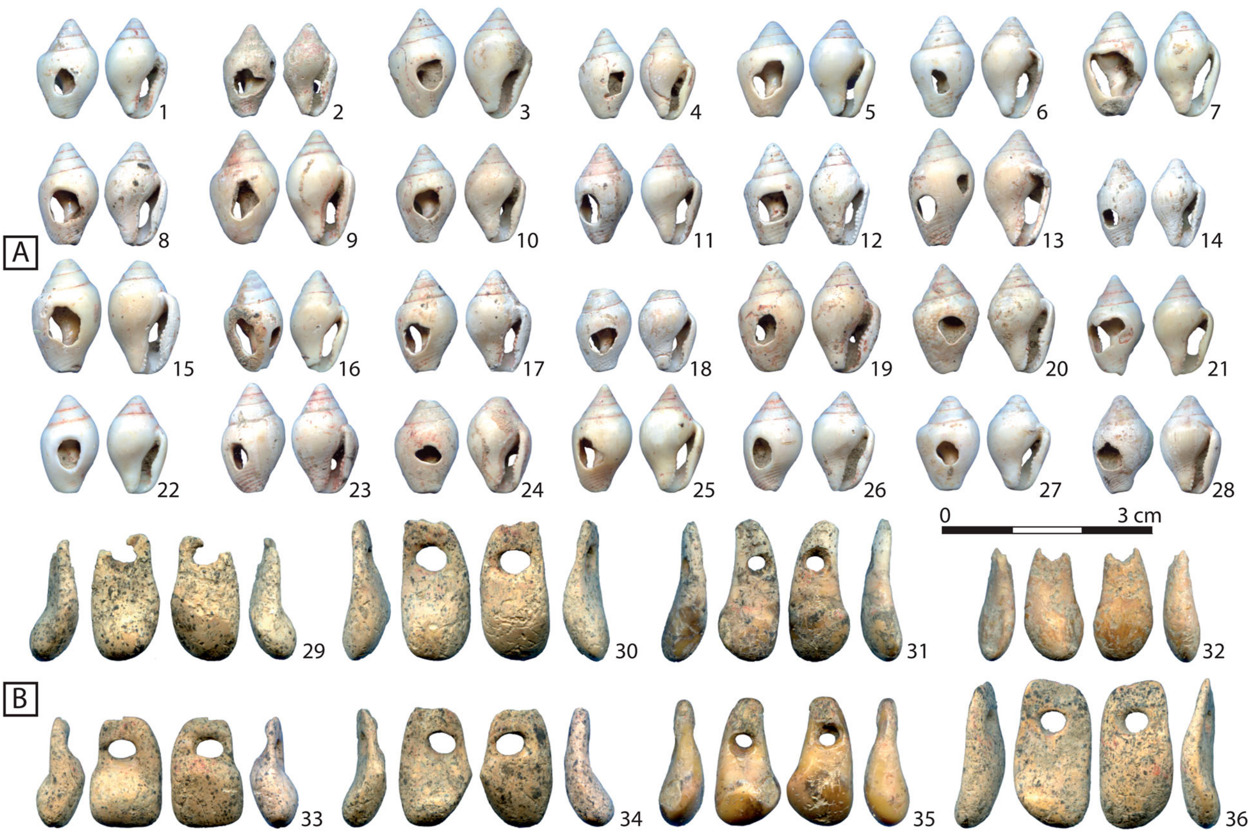

Figure 5. Some of the *Columbella rustica* shells and red deer canines (Photographed by S. Bonnardin).

The burial practices

The individual was buried on his left side in a contracted position (FIGURES 2, 4, 7). The upper right limb is slightly flexed at the elbow while the lower limbs are more strongly flexed, as the right foot bones are near to the pelvis. No grave pit was detected during the original excavation.

The absence of the skull, the first cervical vertebra, and the left superior limbs indicates a deep but localized disturbance, wholly compatible with the Medieval digging of a pit whose limits were clearly visible (FIGURE 7) and several hand bones were found inside it.

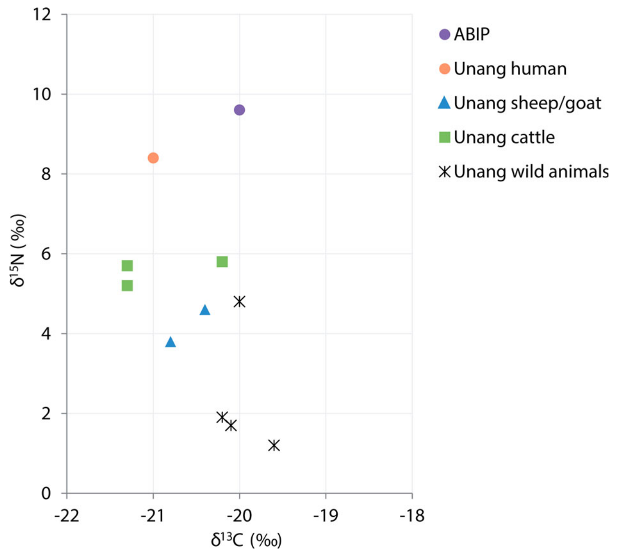

Figure 6. Distribution of carbon and nitrogen stable isotope ratios of ABIP human and Malemort-du-Comtat-Unang (Unang) human and animal remains (created by G. Goude).

The shoulder girdle is complete but its articulations are not preserved. The articulation of the right shoulder is preserved and the upper right limb is flexed at the elbow at an angle slightly more than 90°. The articulation of the elbow is preserved and the radius-ulna set appears in the posterior view, the distal extremity oriented towards the east-northeast. The right carpal and metacarpal are absent. Several bones of the left hand were placed in an incoherent anatomical relationship on the sediment added before the exhibition of the grave. However, the two distal phalanges of the left hand discovered in situ and close to the fifth cervical vertebra indicate that the left hand was initially near the neck. The upper left limb must have been strongly flexed at the elbow and pulled back along the thorax.

The rib cage did not totally retain its original anatomical position. The right ribs are disarticulated from the thoracic vertebra. The right hemithorax appears to have tipped towards the rear and the bottom of the body. The left ribs mostly appear in superior view, the vertebral extremity facing south. The left hemithorax underwent flattening and a slight movement towards the rear.

The pelvis is in loose anatomical connection. The sacrum is turned to the back of the body. Displacements are limited to the internal volume of the pelvis and the connection between the sacrum, which appears in the anterior view, and the fifth lumbar vertebra, is preserved. The left hip bone appears in the medial view, the superior face oriented towards the north while the right one appears in the lateral view, the upper face facing northwest.

The lower limbs are very poorly represented. Most of the bones have been destroyed and the remaining elements

Table 1. AMS dates on human collagen samples from Avignon–La Balance-Ilot (ABIP). Calibrations after OxCal v4.2.3 (Bronk Ramsey 2013).

Field reference	Lab reference	Radiocarbon measure B.P.	σ	Calibrated range B.C. (2σ)	Calibrated range B.C. (1σ)
ABIP#Burial#extract1	LTL-5695A	6047	50	5199-4799	5008-4850
ABIP#Burial# extract2	LTL-5696A	5965	30	4941-4772	4896-4797
ABIP#Burial#R_combine	*LTL5695A -5696A*	*5987*	*26*	*4942-4798*	*4932-4836*

have suffered perturbations. However, the initial position of the lower limbs can be reconstructed. They must have been flexed at the knees, folded up on top of each other and pulled back up to the pelvis. The left femur, represented by its proximal third, has been rotated so that its presents its posterior aspect. A few centimeters away and south of the left femur, the posterior face of the right patella appears. The distal quarter of the right fibula is visible by its medial face, the distal extremity pointed towards the northwest. In the same area, feet bones are a few centimeters south of the right coxal bone.

We can almost fully reconstruct the way the individual was buried. He was laid on his left side, in a contracted position. The upper right limb was flexed and positioned in front of the chest while the left one was probably contracted against the thorax with the left hand at the neck. The lower limbs were heavily folded, placed on top of one another, and aligned with the pelvis. The presence of bones belonging to labile articulations within their anatomical region, including some in a strict anatomical connection, indicates that the deceased was buried shortly after his death and that it is a primary deposit.

Several articulations from all anatomical regions have been preserved (FIGURE 7): the right shoulder, the right elbow, the pelvis and the pelvis with the left thigh. Some elements, such as the right scapula and the right half of the rib cage, were kept in equilibrium. The coxal bone also remained within the internal volume of the corpse. It is therefore assumed that the inhumation pit was filled with sediment immediately after the deposition of the corpse, and that decomposition took place in a plugged space. This hypothesis is supported by the highly reduced fragmentation and the absence of significant displacements, excluding those linked to the later pit disturbance.

We noted the opening of the rib cage, but within a restricted space, as well as the flattening of the left hemithorax which was slightly turned towards the back of the body. This commonly observed movement can be explained by the pressure on the costo-sternal articulations during decomposition, which is accentuated when the corpse lays on its side. Less usual is the fact that all the ribs were affected by this movement in such a uniform manner. This suggests the former presence of a flexible and perishable element on the corpse covering the upper half of the body. A garment, for instance, could have contributed to the maintenance of each hemithorax coherently during the decomposition process. By constraining the decomposition of the rib cage, clothes, such as a jacket, between the corpse and the sediment could thus have limited and determined the dispersal of components of the adornment (FIGURE 8). For example, the swing of the right hemithorax could have created a secondary void where several shell beads would have fallen, explaining the concentrations of shell beads below the right ribs.

Table 2. Stable isotope ratios, element contents and C/N of bone collagen from Avignon–La Balance-Ilot P (ABIP) human (top row only) and Malemort-du-Comtat-Unang human and animal remains.

Sample	Species	$\delta^{13}C$ (‰)	%C	$\delta^{15}N$ (‰)	%N	C/N
Ilot P	human (adult male)	-20.0	42.6	9.6	15.5	3.2
Unang 80 GH-4.5-10	human (adult female)	-21.0	45.1	8.4	14.4	3.6
Caprine EFG	sheep/goat	-20.8	39.5	3.8	13.2	3.5
Caprine H 113	sheep/goat	-20.4	38.6	4.6	13.1	3.4
Bos E 1	cattle	-21.3	41.9	5.2	14.1	3.4
Bos 104	cattle	-20.2	38.5	5.8	13.1	3.4
Bos 3	cattle	-21.3	36.8	5.7	12.2	3.5
Sus 12	wild boar	-19.6	39.5	1.2	13.3	3.4
Cervus 1	red deer	-20.0	49.2	4.8	16.8	3.4
Cervus 2	red deer	-20.2	49.2	1.9	16.4	3.5
Cervus 54	red deer	-20.1	45.3	1.7	15.0	3.5

The Ornaments

PERFORATED *COLUMBELLA RUSTICA*

Around 89% (n = 142 of 158) of the shell assemblage shows a good preservation, i.e., entire shells have smooth and brilliant surfaces. The original colors and decorations are partly preserved on some of them (FIGURE 9A). Only 16 shells are fragmented at the apex and show surface alterations such as a matte and chalky texture and calcareous encrusting on the dorsal or ventral faces.

Each shell has a perforation on its dorsal face (FIGURE 5A). Most of the specimens (n = 156) have a single perforation located in the center of this area, on the first spiral whorl, facing the natural aperture of the shell. Two types of traces have been noticed around these perforations: thin parallel scratches concentrated on a flat and narrow surface around the hole (FIGURE 9C: a, b), and deep incisions on the dorsal side of the shell, which are uni- or multidirectional, sometimes radial (FIGURE 9C: c, d). These patterns suggest that the first type results from abrasion and the second from the scraping of the shell surface with a stone tool. Variations are also observed in the morphology and the dimensions of the holes: they are narrow (FIGURE 9C: a) or broad (FIGURE 9C: g), with a circular, oval, or irregular shape and are between 2.3 and 6.4 mm in size. Modern natural shell assemblages found on beaches also show narrow or broad perforations on the dorsal faces but not such thin scratches on the flat surfaces or scraping traces (Stiner 2003). Thus, the perforations found on the shells from ABIP are clearly of human origin and result from abrasion, scraping, and percussion. Only three specimens have additional perforations located between the dorsal and the ventral faces, very close to the first holes (FIGURE 5A: 2, 13, 16). Even though it is sometimes difficult to determine the natural or human origin of perforations (D'Errico et al. 1993; Stiner 2003), the comparison with modern collections confirms that the second perforation was intentional, at least for one of the shells given its dimensions and the presence of scraping traces along its edges (FIGURE 9C: e, f).

Use-wear patterns in variable locations and shapes were observed on 149 shells (FIGURE 9C: g, h, i). The most frequent

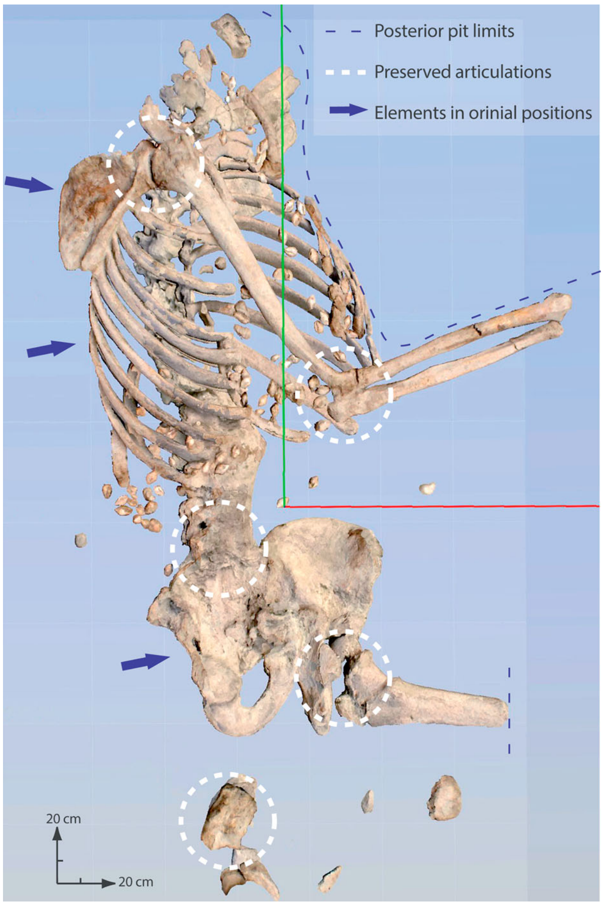

Figure 7. 3D model showing the positions of bones and their articulations (created by S. Sorin and A. Zemour).

patterns are smoothing traces associated with polish on the left sides of the perforations. They certainly result from the friction of string on the edges of the perforations. Flat wear facets have been also identified in several areas (FIGURE 9B): on the dorsal faces close to the perforations (n = 9), on the whorls of the apexes (n = 10), in the centers of the ventral faces (n = 16), at the bases of the shells on the labial sides (n = 14), on the columellar sides (n = 30), or even on both (n = 10). These flat facets could result from the friction of the shells against each other or other hard surfaces. Given the large number of shells in the burial and their locations (FIGURE 8), it is very likely that the friction mainly occurred between the shells themselves. This indicates that they were tied very close together and could have been embroidered on a garment.

PERFORATED RED DEER CANINES

The sixteen perforated red deer canines were affected by biochemical alterations, which limits techno-functional observations. Almost all of them show significant surface exfoliation from the root apex to the top of the crown. Several perforations are broken (n = 3). Only one tooth is well preserved: its smooth surface still exhibits a natural shine (FIGURE 5B: 35).

According to the general shapes of the roots and the locations of the disto-linguo-cervical lobes (Greer and Yeager 1967), six canines belonged to females and 10 to males. Based on the morphological features and on the stage of occlusal wear, at least three potential pairs were identified: one pair of hind teeth and two stag canine pairs (FIGURE 5B: 29–30, 31–32, 33–34). Biometric data from modern and archaeological collections of red deer canines (D'Errico and Vanhaeren 2002) show that sexual dimorphism clearly determines the dimensions of the roots, which are on average wider in stags than in hinds. Such biometric data for the Neolithic of southeastern France are missing, but the neighboring site of Aven des Ibousssières (Malataverne, Rhône-Alpes) dated to the Tardiglacial-Holocene transition (10,370–9190 CAL. B.C.) yielded nearly 200 perforated red deer canines in association with human skeletons and other grave goods (D'Errico and Vanhaeren 2002). All the tooth sizes of ABIP fit the lower values of the female and male populations from Aven des Ibousssières, and some of the stag canines were even smaller (FIGURE 10A). A one-way ANOVA test was applied to the root width of the male teeth from ABIP, Aven des Ibousssières and two other archaeological samples from southwestern France (Saint-Germain-la-Rivière; n = 71) (Vanhaeren and D'Errico 2003) and northwestern Spain (La Braña; n = 24) (Rigaud et al. 2010) (TABLE 3). The results indicate that the Mediterranean population of ABIP differs statistically from the others, which is due to its intermediary position between the average body size of the red deer populations from temperate western Europe and that of the populations from southwestern Europe. This result is in accordance with the general regional and chronological trend observed in the size variation of this species (e.g., Heck 1972).

By applying one of the two ageing methods proposed by D'Errico and Vanhaeren (2002) based on a combination of different morphological variables, it appears that most of the specimens correspond to adult animals between three and 10 years of age. The age profiles created for males and females (by taking into account the range of the estimated ages) differ significantly (FIGURE 10B): in the hind mortality profile, all the age classes are represented with more individuals in the younger classes, whereas fully mature adults (6–8 years old) predominate up to 48% in the stag profile. Despite the low number of elements, it is notable that these results are very similar to those obtained for Aven des Ibousssières (D'Errico and Vanhaeren 2002: 230): a pattern focused on the 6–8 year old animals for the stags and an "attritional," or non-selective, profile for the hind data. Moreover, Aven des Ibousssières and ABIP sex ratios are comparable with approximately one female for two male teeth. The stag profile of La Braña also shows a similar pattern with a major peak in the 6–8 year class, even though there is a lack of 5–7 year old animals (Rigaud et al. 2010).

Beyond the statistical limitations (i.e., sample size) and methodological biases (e.g., variability in the accuracy of the aging method of male vs. female canines, misclassification errors), a first acquisition hypothesis can be proposed. Considering that all the canines were extracted from hunted animals—and not found by chance on natural carcasses—the

Table 3. Q and *p* (same) values obtained for the one-way ANOVA analysis of the root width of male canines from four archaeological assemblages including Avignon-La Balance-Ilot P, The Aven des Ibousssières, Saint-Germain-la-Rivière (SGLR) and La Braña. Except for the assemblages from Aven des Ibousssières and Saint-Germain-la-Rivière (SGLR), the series differ from each other) at a significance level of $p = 0.05$.

Q/*p*(same)	Ilot P	Aven des Ibousssières	SGLR	La Braña
Ilot P		0,003787	1,85E-05	0,01643
Aven des Ibousssières	4,807		**0,523**	7,72E-06
SGLR	6,734	1,927		7,72E-06
La Braña	4,181	8,988	10,92	

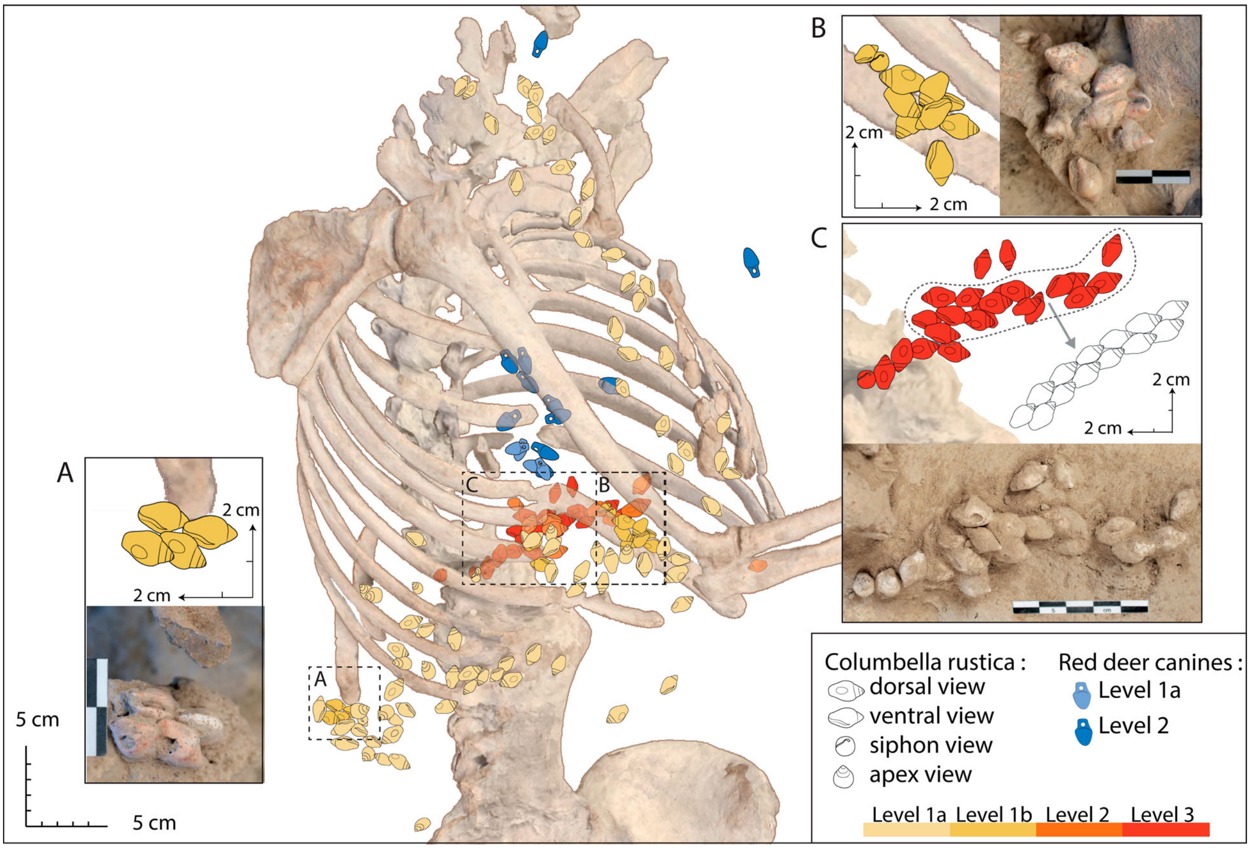

Figure 8. 3D model showing the positions of the ornaments on the upper half of the skeleton. A, B, C): Close-ups of pairs of shells arranged in rows on and under the rib cage (created by S. Sorin and S. Bonnardin and photographs by A. Zemour).

two kinds of profiles correspond theoretically to opposite hunting strategies (Stiner 1991; Lyman 1994) and could be interpreted as the result of the selective culling of prime adult stags (possibly partly related to antler procurement), complemented by a more opportunistic hunting of female herds.

From a techno-functional viewpoint, the canines were perforated systematically on the roots, from the lingual and vestibular faces. Concentric scratches inside the perforations (FIGURE 9D: a, b) imply the use of a pointed stone tool in a continuous rotational movement like that produced by a mechanical bow-drill. In only one case (FIGURE 9D: c), cut marks related to the extraction of the tooth from the mandible were observed on the edge of the perforations. The latter are elliptic and their locations are variable: at the centre or the apex of the root and near the tooth neck. Perforation size (from 2.3 to 3.5 mm) seems to correlate with canine size: the narrower the tooth, the smaller the perforation. The fact that the canines could be paired indicates they come from the same animal. They were perforated in the same areas, have similar dimensions and thus, could even have been perforated by the same person.

Use-wear patterns show some significant variations between ornaments. Half of the corpus (n = 8) shows grooves on the opposite sides of the perforations, on the vestibular faces, or bilateral deformations of the perforations on the same faces (FIGURE 9D–H). This indicates that the teeth were not hung freely on a string but firmly attached on both lateral sides. The most plausible hypothesis is that they were embroidered on a garment. Two other canines have only one groove (FIGURE 9D: d) or a polished surface inside the perforation (FIGURE 9D: e), suggesting another fastening system. Another tooth shows grooves on the opposite sides of the perforation (on the vestibular and lingual faces) and a curved rounding around the hole. These variations suggest that the canines were strung using different kinds of fastening systems resulting from a special arrangement of the teeth for the ornamentation of the deceased. But they may also indicate that the teeth were used previously for other body ornaments.

RECONSTRUCTION OF THE ADORNMENT

In 1974, the partial excavation of the skeleton revealed about 50 *Columbella rustica* shells aligned from the abdomen to the coxal bone, where some of them were grouped (Courtin 1974; Sauzade 1983). The discovery of 100 additional shells and 16 red deer canines during the 2009 laboratory excavation and the taphonomic analysis of the burial, by suggesting the existence of clothing pieces, radically changed the former interpretation of the adornment as a necklace. The analysis of the 3D recording (FIGURES 4, 8) coupled with the techno-functional characteristics of the artifacts allow us to reconstruct the original appearance of this adornment and to propose that the deceased wore a garment, possibly a jacket with embroidered beads described as follows.

On the front side of the garment, from the neck to the level of the elbow, a broken line is composed of 28 sewn shells (FIGURE 8). Despite a few perturbations due to taphonomic processes, they form a simple vertical design subdivided into three distinct sets: the first set shows the dorsal sides of the shells with the apexes pointed towards the head of the deceased; the second shows the ventral side with the apexes pointed towards the feet; and the third one reproduces the pattern of the first. Within each sequence, couples of shells

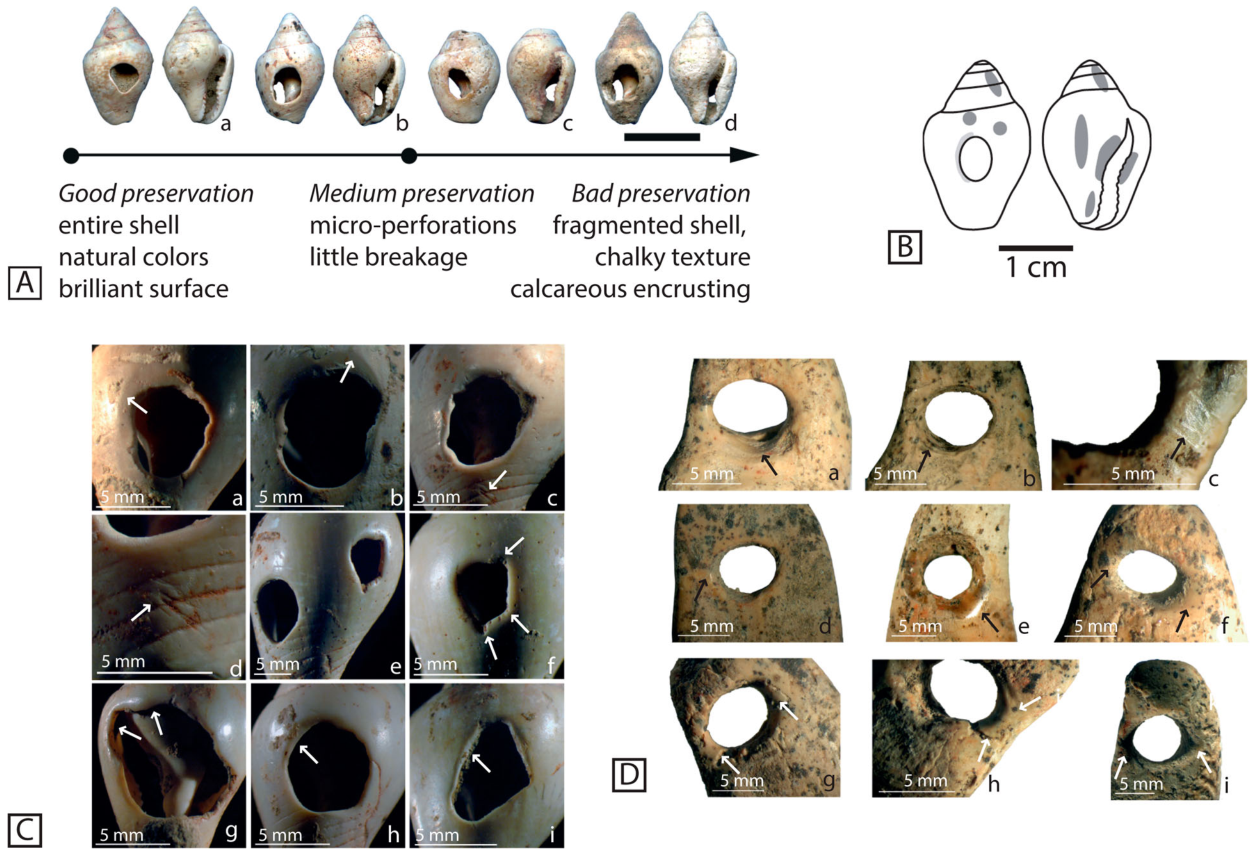

Figure 9. A) State of preservation state of the *Columbella rustica* shells; B) Use-wear traces and distribution patterns observed on the *C. rustica* shells; C) Technological and use-wear traces on the shells (selection): (a-b) flat surface around the perforation suggesting abrasion; (c-d) scratches around the perforation suggesting scraping; (e) double perforation on a shell; (f) close-up of the second hole of human origin on the same shell; (g-i) rounding of the perforation's lateral side resulting from the friction of a string; D) Technological and use-wear traces on the red deer canines (selection): (a-b) rotation traces inside the hole on the vestibular face; (c) striations near the edge of the perforation that may result from the extraction technique; (d) slight smoothing on the linguo-distal part of the perforation; (e) polish of the hole on the lingual face; (f,g,i) bilateral deformation of the perforation on the vestibular face; (h) close-up of the smoothed surface on the vestibular face (photographed by S. Bonnardin).

are sewn top to tail. The aim of these alternating patterns was undoubtedly to create a particular decorative effect.

The right and left bottom sides of the garment have a double border embroidered with shell beads. About 60 are distributed beyond the folded up right arm throughout the right area, with a greater concentration close to the elbow and the lower back (FIGURE 8A, B). Between these areas, the shells appear in the form of a long row, while the remaining elements are scattered near the pelvis and between the ribs. Thirty specimens were grouped by pairs within these three areas (FIGURE 8A). There, use-wear mainly affected the left edges of the shell apertures. Their arrangement indicates that the decorative shell pattern had the shape of a double line of pairs, different from the simple line visible at the front (FIGURE 8). The 30 shells located under the bottom of the left hemithorax allow to reconstruct the ornamental pattern of the left side (FIGURE 8C). Also probably bent on a support, they form a continuous and tight line mirroring the line on the garment's right side (FIGURE 8A, B). The paired alignment of several shells was still visible, which suggests that the left side was certainly decorated with a double border embroidered with shells. Assuming that the garment was open at the front, the alternation of *Columbella rustica* shells from one side to another may have formed a fastening system supplemented by a string.

No connection between the *Columbella rustica* shells and the red deer teeth could be discerned. Some canines were found in the neck area but most of them (10 out of 16) were concentrated in the center of the chest (FIGURE 8). Within this concentration, two pairs of canines associated by their perforations were identified. Use-wear traces show various patterns probably related to different kinds of fasteners. Bilateral and unifacial furrows indicate a fastener by the seam, and bilateral and bifacial furrows imply interlacing, whereas the simple blunted edges of the perforations indicate suspension. Furthermore, it is possible that some traces on these elements resulted from their former use. The concentration and arrangement of the canines suggest that they were embroidered side-by-side possibly intercalated by some back-to-back canine pairs.

The coloring matter

Traces of red coloring matter have been detected mainly on the external surfaces of the *Columbella rustica* shells (inside the turns, sutures, and columellar folds) and, to a lesser extent, inside the opercula, along the edges, and at the backs of the perforations (FIGURE 11A, B, E, F). Other traces are visible inside the impressions left by the shells in the sediment (e.g., specimens 79c, B3) and in soil samples J. Despite the fact that the limb fragment (sample 24k36) also showed color traces, pXRD analysis did not provide additional information.

SEM observations, µXRF and SEM-EDS analyses show that red-colored residues contain iron oxide, silicates, and carbonates, with magnesium, sodium, aluminium, titanium

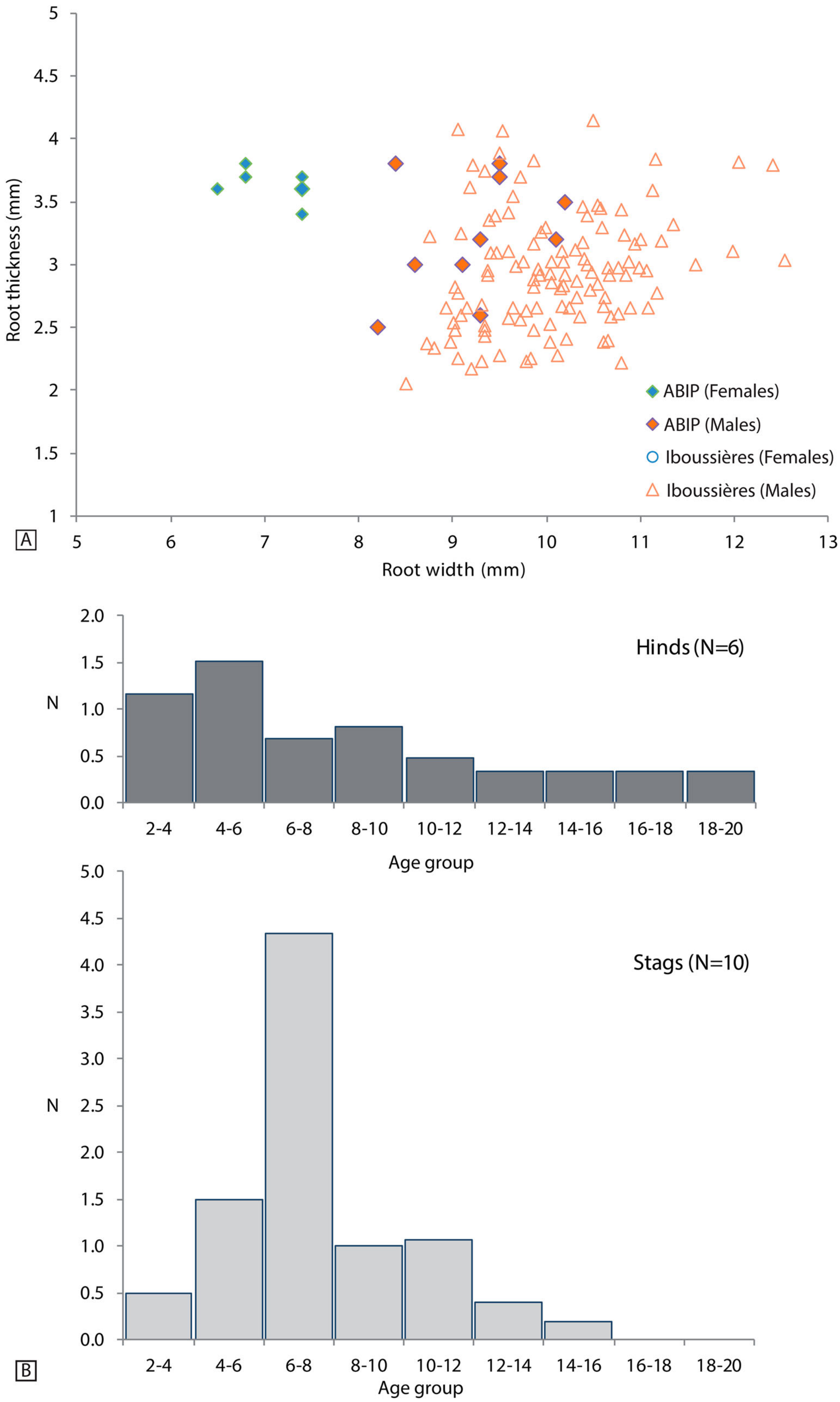

Figure 10. A) Distribution of the root dimensions of male and female red deer canines from ABIP and Aven des Iboussières (Iboussières); B) Female and male age profiles of the red deer canines (age classes in years) (created by L. Gourichon).

and phosphorous elements (FIGURE 11C, D). Elemental analyses provide an average composition of less than 3% iron for about 4% silicium and 10% calcium and 3% aluminium, magnesium, potassium (atomic percentages). Iron oxide corresponds to hematite (p-XRD). We observed 10 µm of aluminosilicates, with sodium and/or potassium. Kaolinite types (d = 7), mica/illite types (d = 10), smectite types (d = 14) clays and feldspar like albite were detected (p-XRD). Titanium was detected in all samples.

The sediment filling the grave consists of calcite, dolomite, quartz, kaolinite and illite (µ-XRD). According to the µ-XRF analysis, the sediment found inside the perforations and the opercula of some *Columbella rustica* shells (n = 3) includes low concentrations of iron, but is not red-colored. Thus,

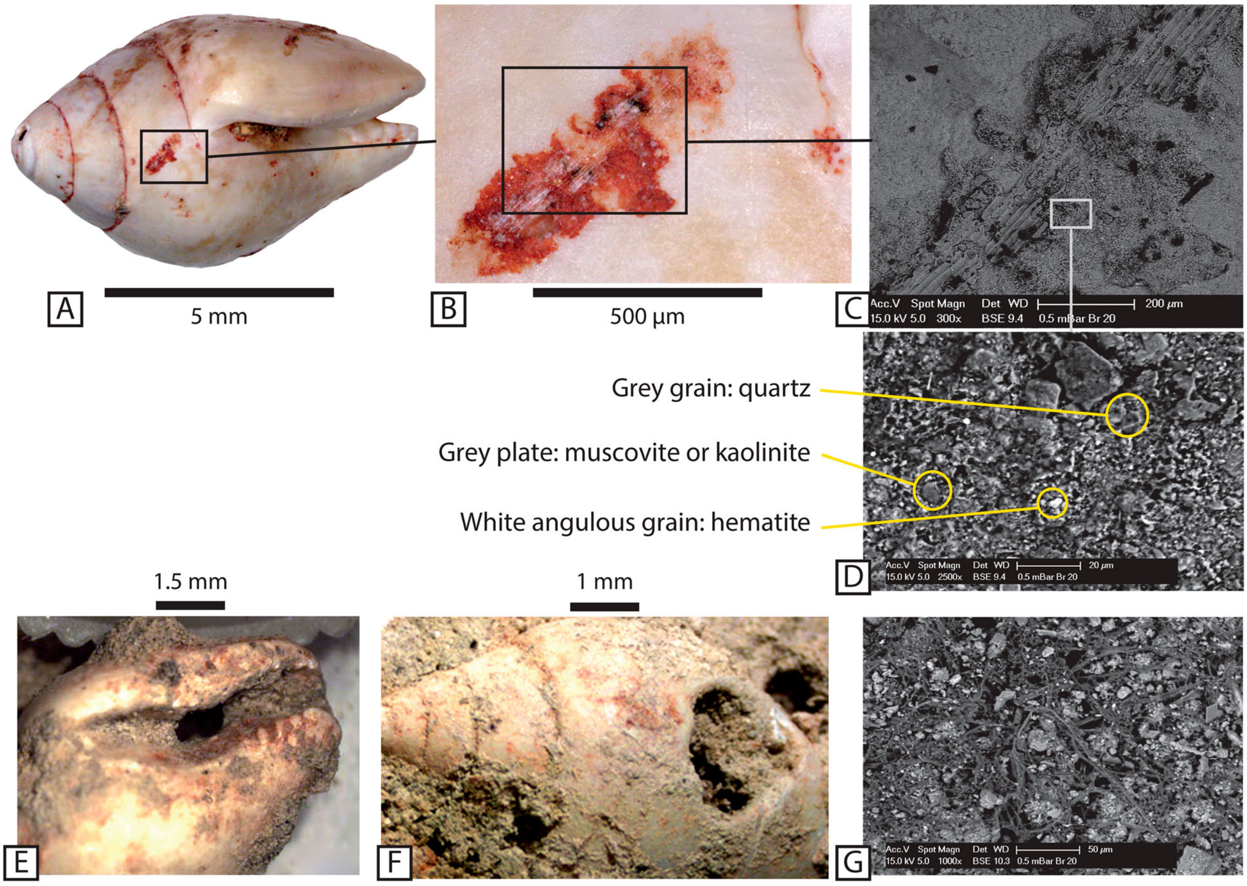

Figure 11. A) Photograph of a red-colored *Columbella rustica* shell; B) Detail of coloring residue; C-D) SEM close-ups of the same color residue; E-F) Others residues; G) Micrograph of organic fiber (A, B, C, D and G, J.-V. by Pradeau and E and F, A.-M. by D'Ovidio).

iron oxide would have migrated into the sediment with water. The presence of goethite (pXRD) and of zinc (µXRF) inside the sediment samples collected from the areas away from the colored shells is probably related to the sediments covering the deceased.

The distribution of the red coloring matter, both inside and outside of the shells, shows they were impregnated after being perforated but prior to the burial. The matter used for coloring contains hematite, kaolinite, quartz, and traces of mica or illite, chlorite or smectite, and feldspars. The possibility of a mixture (iron oxides with clay, silicates, etc.), added to the inability to determine the petrological structures on the basis of such microscopic residues, does not allow a precise identification of the raw materials, especially since the surroundings are rich in potential sources, with ochre deposits and bauxite outcrops known ca. 30–40 km from ABIP (Debrand-Passard et al. 1984). The shape and grading of the iron oxide grains observed under the SEM could provide evidence of grinding action, with two size classes consisting of particles of 1 µm on average and angular grains measuring 5 to 50 µm.

According to the morphology and distribution of the red residues on the shells as well as in areas spatially distinct from them, color was probably used in two different and successive ways. The shells may have been colored: directly by an application of powder or paint, either individually before being assembled or at the same time as the clothing on which they were sewn; or indirectly and progressively by friction, possibly soaked with coloring powder together with the material on which the shells were fastened (string or cloth). Afterwards, a pigment of different origin or resulting from a different preparation (i.e., goethite) may have been sprinkled on the individual during the funeral.

The *Columbella rustica* shells may have been colored for several reasons (e.g., aesthetic or symbolic), in order to encode a message and to transmit it visually (Lock and Symes 1999). Ethnographic studies also mention the use of iron oxides in order to limit the putrefaction of organic matter (Rifkin et al. 2015).

Fibers

During the study of the coloring materials, the stereoscopic and microscopic examination revealed the presence of fibers measuring 5 µm in diameter on the fringes of one shell and in the sediment deposited against the right scapula (Figure 11G). These elements support the hypothesis of the existence of clothing pieces, therefore reinforcing the results of the taphonomic analysis and the study of the ornaments.

Conclusions

The taphonomy of the grave and the study of the ornaments suggest the dead adult man was dressed with a garment covering his chest, possibly a jacket. The latter was decorated with a single line of top-to-tail *Columbella rustica* shells on the front, which could also have been parts of fasteners, and a double border of shells sewn on the left and right sides of the garment. The red deer canines were probably embroidered at chest level. The hypothesis of a decorated garment is supported by the specific organization of the shells surrounding the chest and the pattern of use-wear traces, and is inconsistent with the assumption of a necklace.

To date, this is the first reliable evidence of a garment in a grave dated to the early 5th millennium B.C. in the western Mediterranean. The lack of such remains could be due to the fact that the dead were mostly dressed with garments manufactured only with perishable materials or undressed, but also because ornaments are rather systematically interpreted as pendants, necklaces, etc., and not as clothing components. The physicochemical analyses reveal that red pigments may have been used in two different ways: applied to the ornaments or to the garment before the funeral and sprinkled on the dead during the burial.

In the Early Neolithic of southeastern France, among the few burial structures containing grave goods or ornaments, the materials worn by the dead are clearly predominant (Zemour 2011). Ornaments are variable: bracelets, pendants and beads made from shells, bone or stone materials. Most of these raw materials, difficult to acquire, and manufactured with great effort, appear to be valuable goods. The burial of ABIP appears exceptional regarding the quantity, the manufacturing and the arrangement of ornaments.

The diversity of burial practices throughout the NW Mediterranean has been recently reassessed (Zemour 2011, 2013). Among the primary individual burials from similar contexts discovered in southeastern France, the contracted position on the left side is the most common, but the position of each anatomical region is variable. We note that the ABIP burial has characteristics common with burials from the Square Mouth Pottery (SMP) culture, where the deceased are systematically buried in a contracted position on the left side (Bernabo Brea et al. 2007).

Placing the ABIP burial, dated to ca. 4950 and 4800 B.C. (2σ), in a cultural perspective is rather difficult due to the scarcity of data available for the late 6th and early 5th millennia in the area between the Ligurian Apennines and the Lower Rhone valley (FIGURE 1). Within the lower Rhone basin, a recent reassessment demonstrates that the latest aspects of the IC complex are dated to between 5200 and 5000 B.C., and are situated in the eastern Languedoc (Epicardial phases from Remoulins—Taï cave and Nîmes—Mas de Vignoles X) and western Provence (latest Cardial phases from Courthézon—Baratin and from Lamotte-du-Rhône—Petites Bâties) (Manen et al. 2010).

Between 5000 and 4700 B.C., a restricted amount of data, including only a few reliable radiocarbon dates from Châteauneuf-les-Martigues—Font-des-Pigeons, Jouques—Adaouste, Lamotte-du-Rhône—Petites-Bâties, and Venasque—Céron (Binder and Lepère 2014) provide evidence of Postcardial aspects derived from the IC tradition, visible both in the lithic technology and pottery shaping, but with specific features such as plastic decoration on pots.

This Late Cardial and Postcardial sequence significantly differs from the cultural aspects observed eastwards during the same period, with the emergence and development of Pre-Chassey aspects in central Provence and, further, with the very first evidence of the SMP in Liguria (Binder and Lepère 2014). On the other hand, Postcardial connections have been identified northwards in the Rhone valley with several pottery assemblages showing plastic decoration (e.g., Beeching 1995).

The radiocarbon age obtained for the ABIP burial has an exact correspondence with the date available for the close postcardial deposits of Venasque—Céron. The latter was unfortunately obtained with unidentified wood charcoal, heightening the probability of being affected by the old wood effect (TABLE 4). This open-air settlement, located ca. 30 km east of Avignon (FIGURE 1: 11) yielded a set of pits

Table 4. Dates of Neolithic Liguro-Provence sites during the first half of the 5th millennium CAL B.C.; all are AMS dates except for *Venasque–Céron*. Calibrations after OxCal v4.2.3 (Bronk Ramsey 2013).

Field reference	Laboratory reference	Radiocarbon measure B.P.	σ	Calibrated range B.C. (2σ)	Material used	Bibliographic references
Nice – Giribaldi Str_1	GrA-21350	5740	60	4718-4548	Charred cereal seeds	Binder et al. 2008
Peillon – Rastel Str_Burial	KIA-28339	5770	41	4718-4522	Human bone collagen	Le Bras-Goude et al. 2006
Malemort – Unang Burial_80#1	LTL-8481A	5796	45	4822-4500	Human bone collagen	this work
Finale – Pian del Ciliegio US_54	Beta-77356 (ETH-13181)	5810	70	4830-4497	Short life charcoal	Del Lucchese 2009
Salernes – Fontbrégoua Layer_38	OxA-24705	5862	34	4827-4618	*Sus scrofa* bone collagen	this work
Lamotte-du-Rhône – Petites Bâties Str_11814*	Beta-103864 (OxA)	5870	40	4839-4617	*Quercus* sp. charcoal	Binder and Sénépart 2010
Finale – Arene Candide Layer_7D	Beta-109620	5910	30	4844-4715	Short life charcoal	Binder et al. 2008
Cavalaire – Centre-Ville Str_F1011	Poz-23391	5960	40	4941-4729	*Erica* sp. charcoal	Binder and Sénépart 2010
*Venasque – Céron Silo**	*Gif-9997*	*5990*	*75*	*5199-4707*	Quercus *sp. charcoal*	*Buisson-Catil 2001*
Finale – Pian del Ciliegio US_165C	Beta-109796	6000	60	5039-4729	Short life charcoal	Del Lucchese 2009
Salernes – Fontbrégoua Str_H3#b	GrA-38329	6055	35	5047-4848	Human bone collagen	Le Bras-Goude et al. 2010
Salernes – Fontbrégoua Str_H1#2	GrA-38335	6065	30	5054-4851	Human bone collagen	Le Bras-Goude et al. 2010
Malemort – Unang Burial 80#5	LTL-8480A	6107	45	5200-4804	Human bone collagen	this work
Salernes – Fontbrégoua Str_H3#c	GrA-38332	6110	35	5208-4943	Human bone collagen	Le Bras-Goude et al. 2010
Salernes – Fontbrégoua Str_H1#3	GrA-38522	6115	35	5208-4943	Human bone collagen	Le Bras-Goude et al. 2010

* Possible Old Wood Effects.

including well preserved silos. The material culture illustrates the latest aspects of the IC tradition: pots dedicated to cooking and other uses and large storage vessels bearing plastic decorations. The lithic industry, with the frequent use of the punch technique, is clearly rooted in the IC blade-making tradition (Buisson-Catil 2001; Binder and Sénépart 2004).

To date, none of the burials from southern France and Italy have provided any funeral garments or ornaments for comparison. It is notable that despite the fact that *Columbella rustica* shells such as those found in the ABIP burial are the most common adornments during the early 5th millennium in the northwestern Mediterranean, their numbers are the highest ever observed. Moreover, the presence of red deer canines is unique in the region. Thus, comparisons must be made, far to the North, in the contexts of the Linearbandkeramik (LBK) or Stichbandkeramik (SBK) burials from continental Europe.

The date of the ABIP burial exactly fits the Final LBK (Rubané Final du Bassin de la Seine)/Early VSG (Villeneuve-Saint-Germain), as well as the Hinkelstein (Meunier 2013), contexts in which red deer canines are used to adorn funeral garments. Attributed to the Final LBK, the site of Bucy-le-long, la Fosselle, located more than 700 km northwards in the Paris Basin, yielded the most comparable adornment assemblage. Indeed, this burial comprises 72 red deer canines with the same characteristics as those found at ABIP (Bonnardin 2009). Both burials suggest the existence of relationships between southern and northern France.

Connections between the IC and LBK/SBK spheres covered a rather long timespan beginning at least 5200–5100 B.C., according to the typology of the few LBK pots discovered in southern contexts and particularly at Cheval Blanc–Vidauque cave, situated ca. 30 km southeast of Avignon (Jeunesse and Van Willigen 2006). Vidauque's pot decorations as well as those from Clermont-Ferrand—Le Brezet (Vernet 2004) point to syncretic influences from the Seine Basin and Alsace at the beginning of the Late LBK (Lefranc 2013).

Cardial influences are perceptible in pottery styles from Yonne at the very end of the Late LBK (Rubané Récent du bassin de la Seine), i.e., around 5000 B.C., with the development of plastic decoration (Meunier 2008). White limestone bracelets found in a set of LBK settlements have also been assigned to a southern origin, i.e., the Cretaceous (Urgonian) deposits that surface at few km from Avignon. These bracelets, exclusively associated with the final phase of LBK in the Paris Basin (RFBS), are dated around 5100–4900 B.C. (Constantin 2013; Meunier 2013).

The shell ornament trade also reinforces the existence of concrete links between both cultural areas. *Columbella rustica* trade from the Mediterranean towards the high Rhine and Danube valleys is a long story, starting at least during the Late Mesolithic, e.g., with thousands of Mediterranean shells associated with the skull deposits of Große Ofnet dating from the 7th millennium B.C. (Rigaud 2011). Later, within the LBK/SBK, Mediterranean beads of *Columbella* or *Cardium* are very common (Jeunesse 1993; Bonnardin 2009).

ABIP funeral dress and ornaments could be of LBK tradition, providing another example of intercultural networks and social interactions on a broad scale throughout Europe, which are already illustrated for instance by the jade trade from the Alps whose peak also corresponds to the 5th millennium (Pétrequin et al. 2012).

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A. Zemour led the excavation with the collaboration of F. Le Mené and I. Sénépart. K. Y. Cotto defined the 3D recording strategy. S. Sorin did the 3D data gathering and reconstructions. A. Zemour designed the study and performed the anthropological and taphonomic analyses. G. Goude performed the isotopic analysis. L. Buchet did the paleopathological diagnosis. Palynological tests were made by Bui-Thi Maï (CNRS-CEPAM). S. Bonnardin and L. Gourichon analyzed the ornaments. D. Binder, S. Bonnardin, and A. Zemour wrote the chrono-cultural synthesis. Analysis of the coloring matter was conducted by A.-M. D'Ovidio, J.-V. Pradeau, and P. Bromblet. We thank F. Valentin (CNRS-ArScAn) for her constructive comments on this paper. All the coauthors read and accepted the submitted version of this article.

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