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Research Article

Update and synthesis of the available archaeological and geochronological data for the Lower Paleolithic site of Loreto at Venosa (Basilicata, Italy)

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Abstract

In the Basilicata region, located in southern Italy and known for hosting among the first occurrences of the Acheulean culture in south-western Europe, the Lower Paleolithic site of Loreto at Venosa is located less than a kilometer from the emblematic site of Notarchirico and less than 25 km from Cimitero di Atella. The Loreto site has not been studied as thoroughly as the two other sites and, although geological investigations have been carried out in the Venosa basin, no direct numerical dating has ever been published for the three archaeological levels brought to light during the excavation campaigns. We present a multi-method geochronological approach combining ESR/U-series, ESR, and $^{40}Ar/^{39}Ar$ permitting to refine the age of the most ancient archaeological level (A) of the Loreto site. These data allow us to propose an MIS 13 age for this level, in accordance with previous hypotheses based on geological and paleontological data. We also propose a technical review of the lithic tools preserved in the collection of the National Archaeological Museum of Venosa to integrate Loreto in the evolution scheme of the European Acheulean techno-complex emergence and diffusion.

Keywords: Southern Italy, $^{40}Ar/^{39}Ar$ dating, ESR/U-series, ESR, Monte Vulture

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INTRODUCTION

Discovered at the beginning of the twentieth century, the Lower Paleolithic archaeological site of Loreto is located within the Venosa basin (Basilicata) in the southern part of the Italian Peninsula, only several meters from the famous Acheulean site of Notarchirico. Both sites are located less than 15 km NE of the Mount Vulture volcanic complex (see Fig. 1).

The first archaeological excavation area was opened at Loreto during a short period in 1932 (Rellini, 1932). Additional systematic excavations were led in the middle part of the last century (Blanc, 1953; Chiappella, 1964; Bonifay 1977; Barral et al., 1978; Baissas, 1980; Alberdi et al., 1988). The more important excavation campaigns, directed by A.C. Blanc and G. Chiapella from the Istituto Italiano di Paleontologia Umana, occurred between 1956 and 1961. A few years later, between 1974 and 1981, the site was reopened on a surface of 20 m^2 under the archeological direction of L. Barral and S. Simone (Musée d'Anthropologie Préhistorique, Monaco; Crovetto, 1993). The various campaigns therefore cover more than 50 years and resulted in the unearthing of three distinct human occupation levels, labeled from the lowest to highest A, B, and C. The archaeological assemblages of the higher levels, B and C, are constituted by evolved Acheulean industries, but, due to the lack of well-preserved outcrops, these two levels unfortunately have been under-studied. The most ancient archaeological level (A), which constitutes the only level securely attributed to the Lower Paleolithic culture, was discovered in 1956 by G. Chiapella and repeatedly excavated (see supplementary material 1 for historical photos of the previous excavation campaigns).

A few centimeters above this level, rare faunal remains and lithics industries were found and described that are similar to those from level A. However, due to the small assemblage, no specific study has been described for this horizon.

The nearby site of Notarchirico, which was discovered later in 1979 and excavated over more than 30 years by M. Piperno's team (Università di Roma "La Sapienza"), allowed the individualization of 11 archaeological horizons and the discovery of a human femur (Piperno et al., 1999). Geochronology of the site was previously

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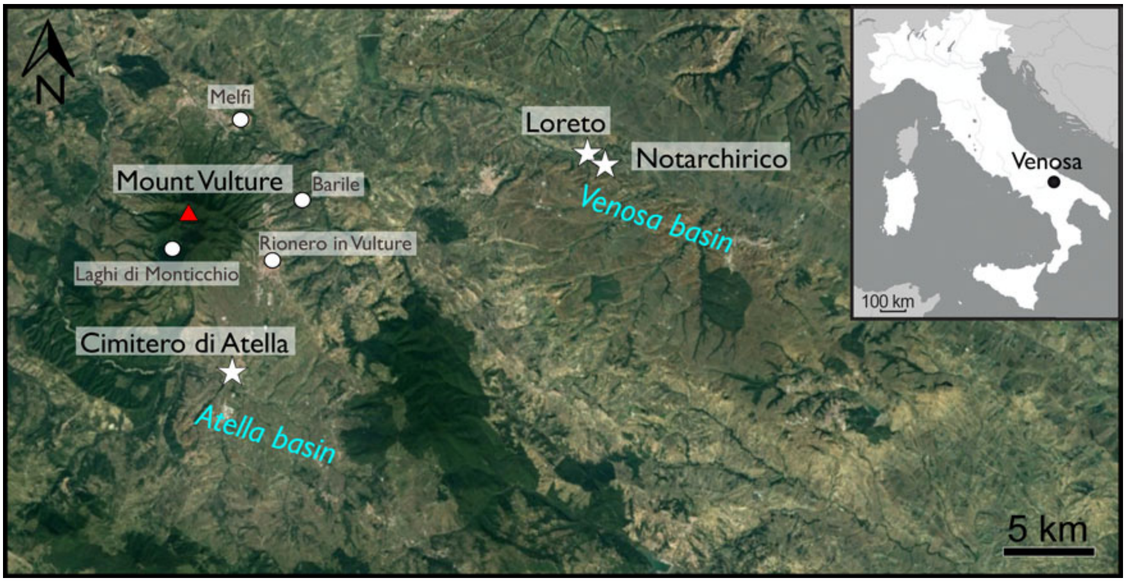

Figure 1. Satellite image from of the study area (Google Earth software). The archaeological sites of Venosa Loreto, Notarchirico, and Cimitero di Atella (white stars), as well as the towns and lakes (white dots) that gave their names to the main volcanic synthems of the Mount Vulture area are located.

based on TL dating (Lefèvre et al., 1993, 1999, 2010; Pilleyre, 1999; Raynal et al., 1999), more recently clarified by $^{40}Ar/^{39}Ar$ and ESR dating, to place the most part of the human occupation levels as coeval of the MIS 16 glacial (Pereira et al., 2015). Recently, new excavation campaigns, led from 2018 by M.H. Moncel's team (HNHP, CNRS–MNHN) and starting downward from the lowest archeosurface, resulted in pushing back the emergence of the Acheulean culture in southern Italy to about 700 ka ago (i.e., during a phase contemporaneous with the MIS 17 interglacial; Moncel et al., 2020, 2021). These recent discoveries make this site the oldest Paleolithic site in Italy and one of the oldest in Western Europe associated with typical Acheulean technologies. It also attests that the oldest human remains of the Italian Peninsula currently are well dated.

While the chronology of Notarchirico is now well known, the site of Loreto lacks independent age control and was tentatively attributed to MIS 13 based on geological correlations with the volcanic activity of Mount Vulture (Lefèvre et al., 1999, 2010). However, no direct radiometric age for the sequence has been obtained to date. This article aims to reappraise the geochronological and archaeological contexts of archaeological level A of Loreto in order to make this record part of the discussions focused on the emergence and development of the Acheulean culture(s) in Western Europe. To achieve this goal, we provide a technical review of the lithic tools preserved in the collection of the National Archaeological Museum of Venosa. Regarding the geochronology, we provide new independent ages using several methods commonly employed to date middle Pleistocene archaeological records in Europe and especially in Italy: electron spin resonance (ESR) on bleached quartz, ESR combined with U-series (ESR/U-series) dating on fossil teeth, and $^{40}Ar/^{39}Ar$ on single crystals (Pereira et al., 2016, 2017; Voinchet et al., 2020; Bahain et al., 2021). The ESR/U-series method was used to date horse teeth from level A (sample from the Venosa Museum's collection) while $^{40}Ar/^{39}Ar$ and ESR were used on bleached quartz to date the same level and a younger geological stratum, altimetrically close to Level C, thus allowing us to obtain an age for the site by a stratigraphic framing. While the ESR and ESR/U-series methods provided a direct deposition age for the studied level, the $^{40}Ar/^{39}Ar$ method on single crystals from fluvial deposits (reworked volcanic minerals) is restricted to highlighting the various eruptive events recorded during infilling of the Venosa basin (Pereira et al., 2015).

Geological context of the site

From a geological point of view, the Venosa tectonic basin constitutes a depression progressively filled by fluvial and lacustrine sediments during the middle Pleistocene. Both stratigraphies at Loreto and Notarchirico are characterized by the overwhelming presence of volcanic material (primary as well as reworked deposits), mainly derived from the Mount Vulture stratovolcano, which was very active during the middle Pleistocene (Cortini, 1975; Bonadonna et al., 1993; Giannandrea et al., 2004; Villa and Buettner, 2009). The chronological and spatial relations between Loreto and Notarchirico remained uncertain for a long time, with Loreto being considered older than Notarchirico on the basis of the earliest archaeological assessments (Rellini, 1932). New research based on paleontological and geological data suggested the change in the Notarchirico deposits (Lefèvre et al., 1999, 2010; Raynal et al., 1998).

Mount Vulture volcanic complex

The Italian geology, particularly in the central and southern part of the country, is characterized from the early middle Pleistocene by intense tectonic and volcanic activity. This activity not only created small tectonic basins that are particularly suitable to the preservation of sub-continuous fluvio-lacustrine infilling, but also induced the occurrence of almost continuous deposition of potassic volcanic minerals within these records (Lefèvre et al., 2010). These tectonic basins have contributed to the excellent preservation of both archaeological and paleontological middle Pleistocene sequences, which sometimes cover continuously

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long timescales (such as one or two glacial/interglacial cycles). Such records can be dated using the $^{40}Ar/^{39}Ar$ radio-isotopic technique (e.g., V. Villa et al., 2016; Marra et al., 2018; Moncel et al., 2020).

In Basilicata, the main volcanic source that was very active during the middle Pleistocene was the Mount Vulture composite volcano. This volcano culminates at 1327 m asl and is the only volcanic edifice located on the eastern belt of the southern Apennines. Very active between about 800 ka and 100 ka, the origin of this volcano is not fully understood but is clearly spatially associated to a NE–SW trending lithospheric discontinuity during subduction of the Adriatic plate (Doglioni et al., 1994; Giannandrea et al., 2004; Schiattarella et al., 2005; D'Orazio et al., 2007). While usually integrated within the Campanian magmatic province, this volcanic edifice is significantly different from the other Italian complexes. Indeed, in addition to the specific geographic position of Mount Vulture, its eruptive products, enriched in sodium and potassium, demonstrate compositions that are distinct from the peri-tyrrhenian Pleistocene volcanoes in central and southern Italy (Peccerillo, 2005). While this complex was mainly characterized by explosive activity, lava flow events also are documented (Brocchini et al., 1994; Villa and Buettner, 2009).

In the early 2000s, a new geological map of the Mount Vulture area was published (Giannandrea et al., 2004; Giannandrea, 2006) and an updated stratigraphic subdivision of the Mount Vulture products was proposed. This classification divides the deposits into units named UBSU (unconformity bounded stratigraphic units), which allowed the linkage of volcanism and local tectonic activity (Giannandrea et al, 2004). Subsequently, these units have been observed within the surrounding fluvio-lacustrine sequences of the Atella, Melfi, and Venosa basins. These UBSU are divided in two supersynthems, containing synthems, which themselves are divided into subsynthems. All these subdivisions are bounded by unconformities (Giannandrea et al., 2004; Giannandrea, 2006). The two supersynthems, which are named Monte Vulture and Monticchio, are stratigraphically separated by a paleosol identified as a geological marker labeled M18. The various synthems and subsynthems identified as well as their chronological boundaries (La Volpe and Principe, 1994; Giannandrea, 2006) are presented in Table 1. The geochronological constraints presented in this table synthetize the published $^{40}Ar/^{39}Ar$ data (Giannandrea, 2006; Villa and Buettner, 2009), all recalculated according Renne et al. (2011) using the K total decay constant and the optimization calibration of the monitor flux standard ACs-2 proposed by Niespolo et al. in 2017 (i.e., 1.1891 Ma). Dates reported are very imprecise and should only be considered as approximate ages of the various eruptive units.

Venosa basin and Loreto archaeological site

The Venosa basin is a large structural depression filled by lacustrine–fluvial deposits. It is oriented NW–SE and extends on more than 50 km from the Apennines chain (Apennino Lucano relief) and Mount Vulture volcano in the west to the Murge plateau in the east (Lefèvre et al., 1994, 1999). Geological investigations in the basin that were led at the end of the 1990s described and correlated the sediment infill using tephrostratigraphy to the volcanic activity of Mount Vulture (see Table 1) (Lefèvre et al., 1994, 1999, 2010; Raynal et al., 1998).

The sedimentary infilling of the Venosa basin is divided in three lithostratigraphic units ("Formations") that were defined in the central part of the basin by the study of various outcrops and quarries (Lefèvre et al., 1994, 1999, 2010; Raynal et al., 1998). Two nested volcano–sedimentary formations, named "Piano Regio Formation" (PRF) and "Tufarelle Formation" (TF) rest on conglomeratic fluvial deposits named "Fonte del Comune Formation" (FCF) (Lefèvre et al.,1999, 2010) (Fig. 2a). Their volcano–sedimentary facies, very rich in pyroclastic materials, have allowed correlation with the Mount Vulture eruptive units (Table 1; La Volpe and Principe, 1994; Giannandrea, 2006; Lefèvre et al., 1999, 2010; Vernet et al., 1999). The Fonte del Comune Formation is contemporaneous with the first phases of regional activity and have been correlated with the Spinoritola subsynthem at the base of Foggianello synthem. The Piano Regio Formation, composed of pumice-rich pyroclastic flows, plinian pumiceous fallouts, and phreato-magmatic deposits, have been correlated with the Fara d'Olivo, Toppo San Paolo, and Rionero subsynthems (see Table. 1). The Notarchirico site belongs to the upper part of the Piano Regio Formation (Raynal et al., 1999; Lefèvre et al., 2010)

The Tufarelle Formation, first described by Piccarreta and Ricchetti (1970), has been divided in four main lithological units labeled members A, B, C, and D (Lefèvre et al., 1999, 2010). These descriptions were based on natural outcrops and quarries in the central part of the basin, (see Fig. 2a and b). The Tufarelle Formation lies directly on a conglomeratic bank of fluvial deposits of the Fonte del Commune Formation and is nested in the Piano Regio Formation. At the base, member A of the Tufarelle Formation is composed of highly heterometric unsorted conglomerates, coarse-grained sands, and scattered meter-size boulders formed by hyper-concentrated lahar flows. Member B (∼10 m thick) is composed of a succession of epiclastites, gray scoria fallout deposits, and horizontal lacustrine limestones. Member C, which is mainly a palustrine environment, as illustrated by the alternance of thick limestones banks, is less epiclastic, containing yellow silts, hydromorphous paleosols, and an encrusted emersion surface. Finally, member D is mainly constituted by greenish-gray clays that are more or less rich in volcanic sands and interspersed with reworked tephra layers and volcanic sands rich in clinopyroxenes. The Tufarelle Formation has been correlated with the San Michele subsynthem and the Melfi synthem (see Table 1).

At the Loreto excavation site (40°58′32.60″N, 15°52′30.33″E), the stratigraphy consists of a 30-m-thick sequence in which 42 distinct sedimentary levels have been identified (Baissas, 1980; Barral and Simone, 1983) (see Fig. 3). A composite sequence of the site has been constructed based on the study of several records from the hill of Loreto, for which the site was named (Baissas, 1980; Barral and Simone, 1983). Indeed, the small outcrops on the slope of the the hill have been compared to a drill core collected in 1988 (Lefèvre et al., 1999, 2010). This core, labeled Vn 88-1, was drilled from the top of the hill to a depth of 40 m (see Fig. 2a and b). Three human-occupation levels, A, B, and C, have been documented (Barral and Simone, 1993). The sedimentary layers corresponding to these levels are indicated on Figure 2b and Figure 3.

Baissas (1980), thanks to acquisition of palaeomagnetic data along the different outcrops, identified the Brunhes/Matuyama boundary in levels 37–38 (e.g., 775–780 ka). Gagnepain (1996) identified a reverse polarity at around −32 m in core Vn-88-1, which is 5.5 m below level 37 of Baissas, 1980 (−26.5m in the core). The Brunhes/Matuyama boundary must be reinterpreted within the framework of the litho-stratigraphic succession

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Table 1. Synthesis showing the various volcanic and sedimentary subsynthems of the Mount Vulture Volcano (modified from Giannandrea, 2006). The Venosa basin formations are correlated by tephrostratigraphy to the Monte Vulture units (Lefèvre et al., 1999, 2010).

	Monte Vulture		Age $^{40}Ar/^{39}Ar$	*Venosa basin*
Monticchio Supersynthem	Laghi di Monticchio Synthem	Lago Piccolo (subsynthem)	142.4 ± 11 ka (A)	
		Lago Grande (subsynthem)		
		Piano Comune (subsynthem)		
	Valle dei grigi -Fosso del Corbo	Masseria di Cuscito (subsynthem)	498.9 ± 5 ka (B)	
		Imbandina (subsynthem)		
		Case Lopes (subsynthem)		↑?
		EROSION - MARKER M18		
Monte Vulture Supersynthem	Melfi Synth.	Piano di Croce (subsynthem)/ Castello di Melfi	578.6 ± 4 ka (A)	*TUFARELLE Formation*
		EROSION		
	Barile Synthem	Ventaruolo (subsynthem)	< 616 ka (A)	
		EROSION		
		San Michele (subsynthem)	616 ± 8 ka (A)	
		EROSION		
		Rionero (subsynthem)	636.2 ± 20 ka (A) to 721 ± 18 ka (A)	*PIANO REGIO Formation*
		Toppo San Paolo (subsynthem)	679.6 ± 19 ka (A)	
		EROSION		
	Foggianello Synthem	Fara d'Olivo (subsynthem)	Upper < 746 ka (A) Lower 746 ± 12 ka	
		EROSION		
		Campanile (subsynthem)		*FONTE DEL COMUNE Formation*
		EROSION		
		Spinoritola (subsynthem)	680.6 ± 7 ka (C)	

(A) Villa and Buettner, 2009, (B) Brocchini, 1993, (C) Bonadonna et al., 1998. Ages are recalculated according to the monitor flux standard ACs at 1.1891 Ma (Niespolo et al., 2017) and the total K decay constant of Renne et al. 2011.

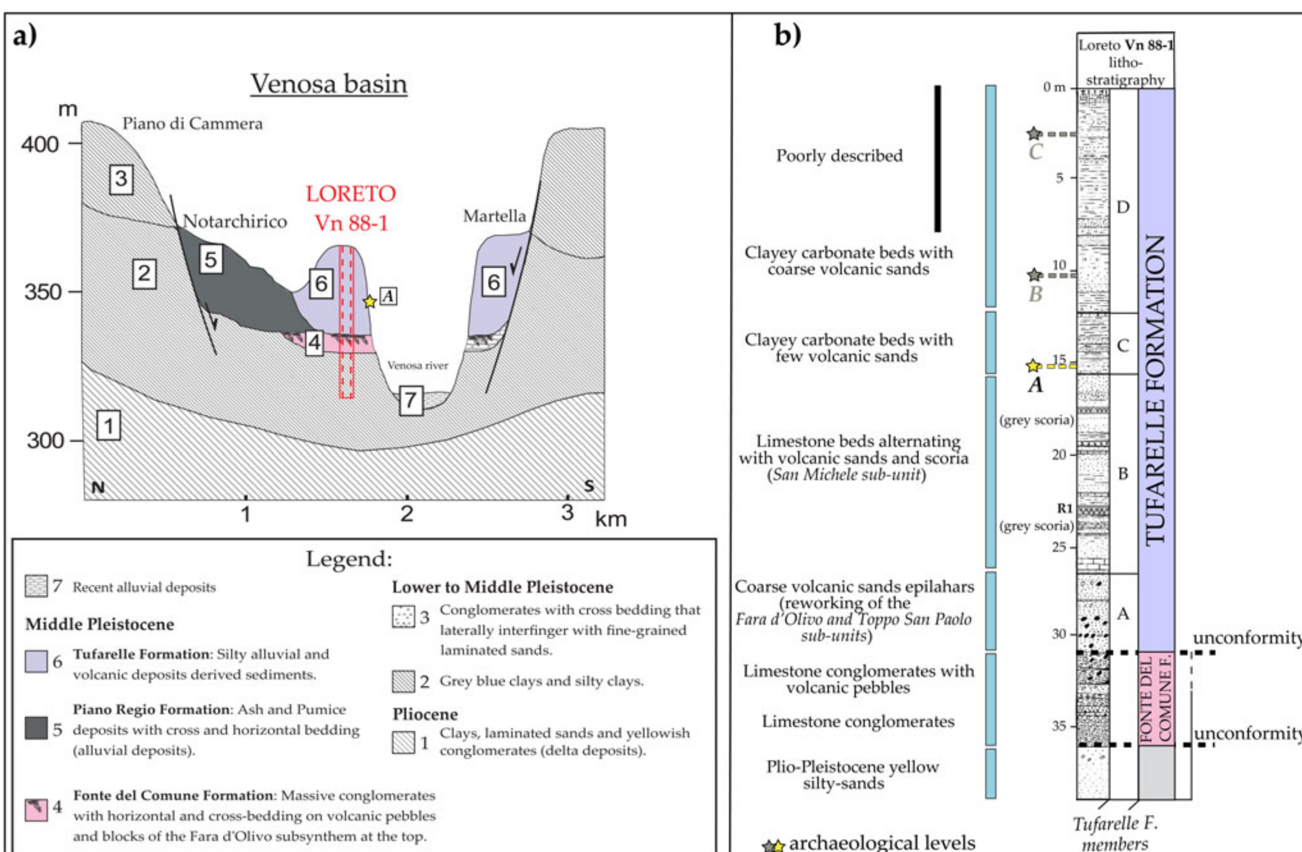

Figure 2. (a) Schematic cross-section of the Venosa Basin showing the location of Loreto hill and Vn 88-1 drilling. (b) Lithostratigraphy of the Vn 88-1 drilling correlated with the Venosa basin formations (redrawn from Lefèvre et al., 1999, 2010); A–D = Tufarelle Formation members; R1 = tephra/volcanic deposit.

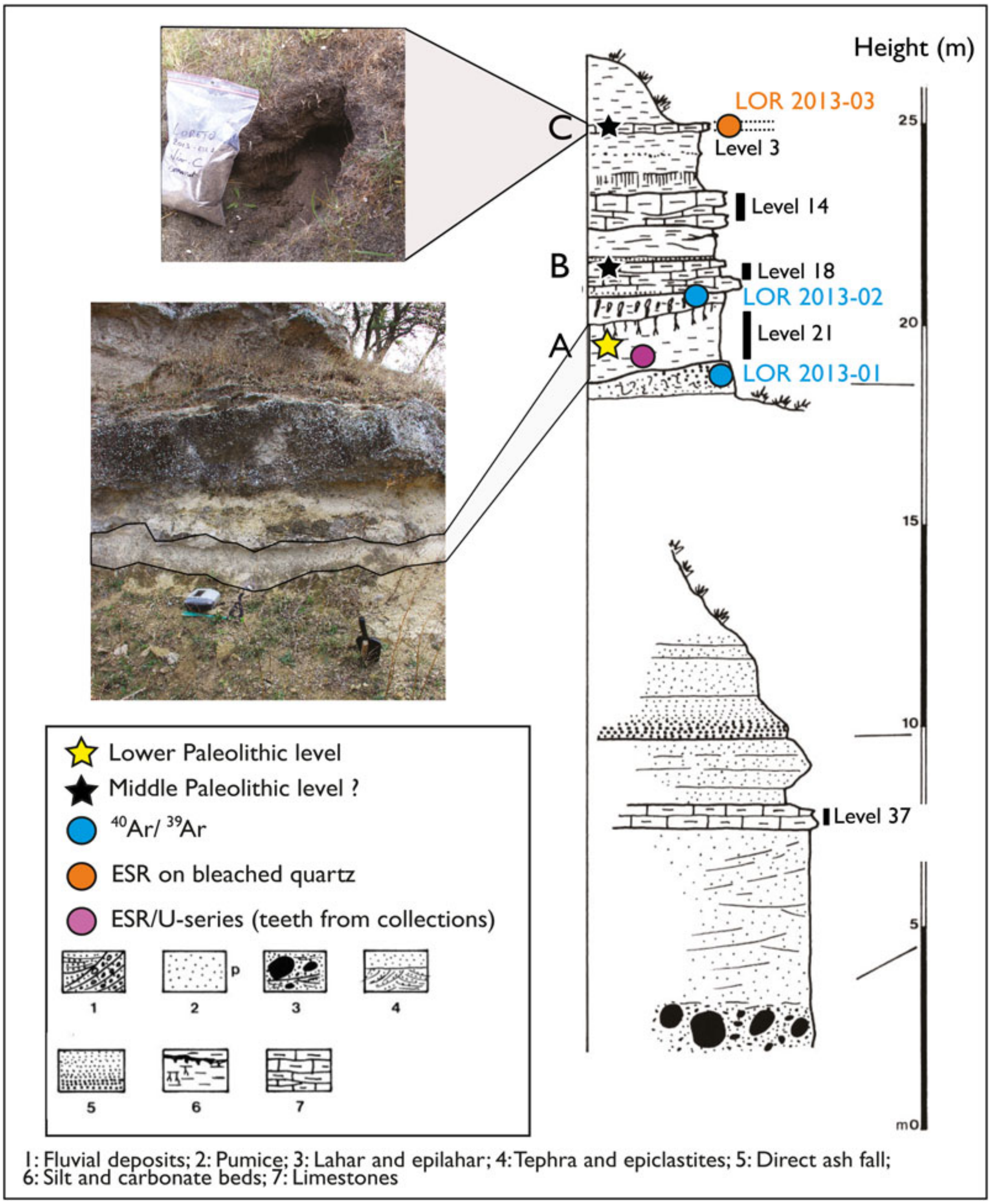

Figure 3. Stratigraphic positions of the samples collected at Loreto (modified from Barral and Simone, 1983; Lefèvre et al., 1994; and Gagnepain, 1996).

identified in the basin and should correspond to the sedimentary unconformity found in the Loreto core at 31.20 m between the conglomerate of the Fonte del Comune Formation and the lahar deposits of basal member A of the Tufarelle Formation (Lefèvre et al., 1999, 2010). Baissas (1980) also identified the "Levantine" and "Jamaïca" paleomagnetic excursions in levels 9–8 and 4–2, respectively (around archaeological level C) (see Fig. 3), which provided preliminary chronological information for the top of the sequence. However, the most recent geomagnetic instability scale no longer suggests the existence of these excursions (Singer, 2014). Rather, the excursions identified in Loreto could be associated with the excursions at Pringle Falls (ca. 210 ka) and Laguna del Sello (ca. 340 ka) or simply be re-magnetization of the sediments.

The conglomeratic deposits observed at the foot of the hill at Loreto belong to the Fonte del Comune Formation, which is the basal stratigraphic unit of the basin fill (Lefèvre et al., 2010). Above, there are highly heterometric unsorted conglomerate, coarse-grained sand, and scattered meter-size boulder deposits formed by lahar flows, of member A of the Tufarelle Formation. Higher on the slope, there are epiclastites and gray scoria-fallout deposits. The tephra layer in level 32 corresponds to fallout R1, a major tephrostratigraphic marker of member B of the Tufarelle Formation (Lefèvre et al., 1999, 2010; Vernet et al., 1999) (see stratigraphic position Fig. 2b). Farther uphill, the deposits become less epiclastic and contain thick limestone banks, yellow silts, hydromorphous paleosols, and a cemented and encrusted emersion surface, which are characteristic of palustrine environments of member C of the Tufarelle Formation. The upper facies is composed of gray clayey carbonate banks with carbonate nodules and ferruginous pisolites and reworked tephras that correspond to member D of the Tufarelle Formation.

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Archaeological level A belongs to member C. The epiclastites of member C may correlate with the Case Lopes subsynthem of the Mount Vulture volcano (Valle dei Grigi–Fosso del Corbo synthem, base of the Monticchio supersynthem; Table 1) (Lefèvre et al., 2010). The epiclastites were estimated to date between ca. 484 ± 8 ka and 530 ± 22 ka (Brocchini, 1993; Villa and Buettner, 2009).

Archaeology and paleontology of level A

The lithic assemblage constituting archaeosurface A was composed almost entirely of Lower Paleolithic lithic industries made of cores, flakes, choppers, and chopping tools in limestone or flint. It is worth noting that only one tool named "proto-biface" has been found (Barral and Simone, 1983) (see supplementary material 1 – S1 and S2). Technical and typological characteristics of the series have led to their attribution to the historical "Tayacian culture" (Di Cesnola and Mallegni, 1996; Piperno et al., 1998; Grifoni and Tozzi., 2006). In addition to the lithic industries, traces of human activities, such as butchery cuts, were identified on large herbivore bones, which bring into question the possible functions of butchers based on this archaeosurface (Barral and Simone, 1983). Before any geological investigations, the chronological context of level A, was established based on paleontological assemblage interpretations. Indeed, Bonifay (1977) attributed the large mammal remains found in this layer to the Villafranchian faunal unit, suggesting a possible early middle Pleistocene age for the archaeological vestiges (that we estimate to be ca. MIS 15/16). Furthermore, the abundance of *Equus* remains and the absence of elephant at Loreto prompted paleontologists at the end of the 1980s to support the older age of the Loreto site compared to the Notarchirico age where the *Equus* taxa are completely absent.

Over excavation campaigns, the paleontological assemblage became richer with the addition of taxa such as *Bos primigenius*, *Bison schoetensacki*, *Hippopotamus* sp., and *Stephanorhinus* sp. The faunal assemblage was thus dominated by *Palaeoloxodon antiquus*, *Dicerorhinus etruscus*, *Equus*, *Equus* aff. *E. süssenbornensis*, *Equus altidens*, *Equus hydruntinus*, *Hippopotamus amphibius*, *Bison schoetensacki*, *Megaceros soleilhacus*, *Dama nesti*, *Dama dama*, *Capreolus affinis*, *Capreolus süssenbornensis*, *Ursus deningeri*, *Canis arnensis*, *Canis etruscus*, *Hyaenidae* sp., *Felis pardus*, *Homotherium* sp., and *Oryctolagus cuniculus* (Segre and Piperno, 1984; Alberdi et al., 1988).

These additional paleontological discoveries have resulted in an age interpreted to be older than the Fontana Ranuccio Italian faunal unit, dated to a period contemporaneous with Marine Oxygen Isotopic Stages 13 and 11 (Petronio et al., 2017; Florindo et al., 2021). The *Bison* species found at Loreto was suggested at the time more archaic than the one recovered at Isernia la Pineta, which recently was dated ca. 582–561 ka (MIS 15; Peretto et al., 2015). These different interpretations of the Loreto faunal assemblage make any biochronological age hard to assess.

The synthesis of geological and paleontological data led Piperno et al. (1999) in their Notarchirico monograph to propose an age for level A of between ca. 550 and 500 ka, thus during the period that was contemporaneous with the MIS 13 interglacial phase. A complete re-study of the material and additional independent geochronological data were therefore necessary.

SAMPLING AND METHODOLOGY

Geochronology

Figure 3 summarizes all sampling done for geochronological studies directly on the Loreto hill composite stratigraphic sequence. Samples from two stratigraphic levels were collected for $^{40}Ar/^{39}Ar$ analyses (LOR 2013-01 and LOR 2013-02) ∼90 cm below and ∼180 cm above archaeological level A (LOR A), respectively. Four horse teeth in the Venosa Museum's collections (VL-A252, VL-A655, VL-A854, VL-911) were sampled from this level for the ESR/U-series dating analyses. Two samples also were collected to be dated by ESR on bleached quartz. One came from the top of the hill, however the deposit selected turned out to be too much reworked to provide a consistent age. The second was collected approximately 6 m above archaeological level LOR A (named LOR 2013-03), so probably close to the upper archaeological level LOR C in elevation (see Fig. 3).

$^{40}Ar/^{39}Ar$ on single grains

The $^{40}Ar/^{39}Ar$ method was applied to date volcanic minerals found in the Loreto stratigraphic sequence that originated from Mount Vulture eruptive activity. Minerals extracted were individually dated, which allowed us to identify the various volcanic events reworked within the fluvial deposits characterizing Loreto. The $^{40}Ar/^{39}Ar$ dating was done at the Laboratoire des Sciences du Climat et de l'Environnement facility (LSCE–CEA, Gif-sur-Yvette, France). The samples were prepared following the procedure described in Pereira et al. (2015). After crushing, sieving, cleaning with distilled water, and repeated ultrasonic baths, ∼15–20 pristine potassic feldspars, ranging in size between 1 mm and 500 μm, were handpicked. Due to the scarcity of suitable crystals within the samples, all the unaltered crystals found were selected. After a short leaching in a 7% HF acid solution (5 min) in order to remove unwanted potential particles aggregated on the surfaces of the crystals, the samples were then loaded on an aluminum disk and irradiated for 60 minutes (IRR 85) in the ß1 tube of the Osiris reactor (CEA, Saclay, France). After irradiation, about 15 crystals for each sample were loaded individually in a copper sample holder that was then put into a double vacuum Cleartran window. Individual fusions of the K-feldspars were provided using a 25W Synrad CO_2 laser at about 10–15% of the nominal power. The extracted gases were then purified for 10 min by two hot GP 110 getters (ZrAl). Argon isotopes (^{36}Ar, ^{37}Ar, ^{38}Ar, ^{39}Ar, ^{40}Ar) were measured using a VG 5400 monocollector mass spectrometer equipped with a Balzers 217 SEV SEN electron multiplier coupled to an ion counter. The full analytical protocol can be found in Nomade et al. (2010). Neutron fluence J was calculated using co-irradiated Alder Creek sanidine (ACs-2) standard with an age of 1.194 Ma ($J_{LOR\ 2013\text{-}01} = 0.0003996 \pm 0.00000200$ and $J_{LOR\ 2013\text{-}02} = 0.0003846 \pm 0.00000077$) (Nomade et al., 2005) and the total decay constant of Steiger and Jäger, 1977. $^{40}Ar/^{39}Ar$ ages cited in this study, including the new ones for Loreto, were recalculated using the most recent optimization calibration of Niespolo et al., 2017, and suggest an age of 1.1891 Ma for Alder Creek sanidine (related to the total K decay constant of Renne et al., 2011). Analytical results were reduced using the ArArCALC V2.4 software (Koppers, 2002), which can be found in supplementary material 2 and 3. Procedural blank measurements were performed after every two or three unknown samples. Mass discrimination correction was monitored by measurements of air argon of various beam sizes and was calculated relative to a $^{40}Ar/^{36}Ar$ ratio of 298.56 (Lee et al., 2006).

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ESR and ESR/U-series

Electron spin resonance (ESR) and combined ESR/U-series (ESR–US) dating methods were applied on Loreto sediments and fossil mammal teeth, respectively. These trapped-charge methods are based on the accumulation of electrons released by natural radioactivity over time in defects of the considered mineral samples. The total dose of radiation absorbed by a sample during its geological history (expressed in grays, Gy) can be extrapolated from ESR analyses, therefore the duration of the natural irradiation, which reflects the age of the sample, is obtained by dividing this total dose by the dose rate to which the sample is submitted yearly. This dose rate is mainly determined from the radionuclide contents of the sample and its immediate environment (sediments) and from cosmic dose contribution. *In situ* and laboratory dosimetry measurements using portable Inspector 1000 Canberra© and laboratory HPGe Ortec© γ spectrometers, respectively, were consequently performed on Loreto sediments.

ESR dating on optically bleached quartz. In the case of sedimentary quartz ESR dating, the dated event corresponds to sediment burial after exposure of the quartz grains to sunlight during the transport phase prior to deposition. This exposure leads to an optical bleaching of the quartz ESR signals, mainly those linked to aluminum (Al) and titanium (Ti) impurity centers. If Ti centers can be quickly (for ESR) and completely bleached by light exposure, the presence in quartz aluminum centers of "deep aluminum traps" (DAT) that cannot be reset by the energy provided by sunlight makes it necessary to determine for each sample the level of "residual" ESR intensity, corresponding to the maximum bleaching of the Al signals into the quartz grains, prior to any age calculation (Tissoux et al., 2012). For aluminum centers, to take into account the part of centers that cannot be reset by light exposure, one aliquot was exposed for 1600 hours to light in a Dr Honhle SOL2 solar simulator (light intensity between 3.2 and 3.4×10^5 Lux). The value of the ESR intensity of this bleached aliquot was then systematically subtracted from the ESR intensities of all the other aliquots (DAT, Tissoux et al., 2012) of the same sample prior to the D_E calculation. A bleaching rate δbl (%), reflecting the relative importance of bleachable and non-photosensitive centers, is determined by comparison of the ESR intensities of the natural (I_{nat}) and bleached (I_{bl}) aliquots: $\delta bl = ([I_{nat} - I_{bl}]/I_{nat}) \times 100$. To minimize this, an ESR multi-center approach that was based on the systematic measurements of both aluminum (Al) and titanium–lithium (Ti–Li) signals was used on the Loreto sample.

In the present work, the samples were prepared as explained by Voinchet et al. (2020). After extraction of the pure quartz 100–200 μm grain-size fraction of the sediments, the sample was split into 11 aliquots. Nine of the aliquots were irradiated at doses ranging between ∼200 and 15,000 Gy using a panoramic ^{60}Co source (Dolo et al., 1996) with a dose rate of ∼200 Gy/h, one aliquot was preserved as reference (natural aliquot), and the last aliquot was exposed to artificial light in a SOL2 Hohle© solar simulator for 1600 hours in order to estimate the residual Intensity of the Al signal. ESR measurements were performed at the MNHN laboratory, Paris, at 107°K with a Bruker EMX spectrometer using the experimental conditions proposed by Voinchet et al., 2004: 5 mW and 10 mW microwave power, 20 mT sweep width, 100 kHz modulation frequency, 0.1 mT modulation amplitude, 40 ms conversion time, 20 ms time constant. Each aliquot was measured three times after a rotation of 120° of its initial position in the cavity. This protocol was repeated on three different days, resulting in nine measurements for each aliquot.

The Al-signal ESR intensities were measured between the top of the first peak at g = 2.018 and the bottom of the 16th peak at g = 2.002 (Toyoda and Falguères, 2003) while the Ti–Li ESR intensities were measured from the g = 1.913 peak bottom and the baseline and the Ti–H intensities were measured between the g = 1.917 peak apex and the baseline (Toyoda et al., 2006) Equivalent doses (D_E) were derived from the obtained intensity growth curves using an "exponential + linear" function with Microcal© OriginPro 8 software with $1/I^2$ weighting (Voinchet et al., 2004) (see supplementary material 1, S3).

The dose rate was determined from radionuclide activities derived both from in situ and laboratory gamma-ray spectrometry measurements. The following parameters were used in the age calculation: dose-rate conversions factors (from Guérin et al., 2011); k-value of 0.15 ± 0.1 (Laurent et al., 1998); alpha and beta attenuations (from Brennan et al., 1991; Brennan, 2003); water attenuation formulae (from Grün, 1994); cosmic dose rate estimated from the Prescott and Hutton's (1994) equations. The internal dose rate was considered as negligible because of the low contents of radionuclides usually found in quartz grains (Murray and Roberts, 1997; Vandenberghe et al., 2008). ESR age estimates are given with one sigma error range.

ESR/U-series on teeth. As mentioned previously, post-mortem uranium-uptake phenomena into dental tissues complicates the estimation of the dose rate due to its associated variation over the time. The age of a given tooth is then deduced from both ESR and U-series data through the modeling of the U-uptake (and eventually leaching) kinetics for each dental tissue. The analytical and mathematical protocols used for calculating combined ESR/U-series ages have been described by Bahain et al. (2021) and Shao et al. (2014), respectively.

The external enamel layer of each tooth was mechanically sampled, cleaned on each side in order to avoid any contamination by sediment, dentine, or cementum, ground, sieved, and the 100–200 μm grain-size fraction extracted. The extracted sample was split into 10 aliquots. One aliquot was kept as natural reference and the other nine were irradiated using ^{60}Co calibrated source (LNHB, CEA, CEN Saclay, France) at exponentially increasing doses until ∼10–20,000 grays (Gy). The ESR intensity of each aliquot was measured at MNHN, Paris, at room temperature using a Bruker EMX spectrometer with the following parameters: 10 mW microwave power, 0.1 mT modulation amplitude, 10 mT scan range, 4 mins scan time, and 100 kHz frequency modulation. At least four measurements were performed for each aliquot on different days. The ESR intensities were measured peak-to-peak (T1–B2) from the g = 2.00018 enamel ESR signal according to Grün (2000). Equivalent doses D_E (see supplementary material 1, S4) were extrapolated from the obtained ESR dose-response curves using "exponential plus linear" function using Microcal© OriginPro 8 software with $1/I^2$ weighting.

U-series analyses were obtained for each dental tissue using the chemical protocol of Shao et al. (2011): 50–150 mg of each analyzed tissue was dissolved in 7N HNO_3 and spiked with ^{233}U, ^{236}U, and ^{229}Th. The solution was then passed through an anion exchange resin column (Dowex 1 × 8; 100–200 mesh) in 8N HCl to fix U, then eluted with 0.1N HCl. The U and Th fractions were purified using a UTEVA resin column in 7N HNO_3 and a second anion exchange resin column in 7N HNO_3, respectively. U and Th were then eluted with 0.1N HCl and 8N HCl,

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respectively. Lastly, for the Q–ICP–MS measurements, purified U and Th were re-dissolved in 0.5N HNO_3. The measurements were then performed using Thermo electron© iCAP–RQ Q–ICP–MS.

The U-uptake parameters, dose-rate contributions, and ESR/U-series ages were then calculated in relation with the U-uptake kinetics (see details in Bahain et al., 2021). Several models combining U-series and ESR data were used in the present study. The US model (Grün et al., 1988) introduces an uptake parameter, p, describing a continuous incorporation of uranium in the considered dental tissue. Because the US model does not allow an age calculation if uranium loss (leaching) occurred after incorporation, Shao et al. (2012) proposed a new model called Accelerating Uptake (AU) model, in which incorporation is described as a process accelerating over time. For the calculations, another uptake parameter, n, is defined to describe the evolution of the uranium content in the tissue under consideration (supplementary material 1, S5). The ESR/U-series age calculations were performed using MATLAB© "USESR" and "AUESR" computer programs written by Shao Qingfeng, in which the age uncertainty (1σ) is calculated with a mathematical algorithm using a Monte Carlo approach (Shao et al., 2014).

The following parameters were used during the age calculation process: k-value (α efficiency) of 0.13 ± 0.02 (Grün and Katzenberger-Apel, 1994); water content of 0 wt% in the enamel and 7 wt% in the dentine and cementum; conversion contents–doses factors from Guérin et al. (2011); for each dental tissue, Rn loss was estimated from both gamma and Q–ICP–MS measurements (Bahain et al., 1992); beta dose contributions were corrected from the enamel part removed on each side of the enamel layer during the preparation process (Brennan et al., 1997).

Lastly, in order to evaluate the quality of the paleodosimetric reconstruction, an isochron diagram (Blackwell and Schwarcz, 1993) displaying the individual equivalent dose values versus the total internal dose modeled by ESR/U-series for the analyzed teeth was for the dated level A. Both the relevance of the dose rate reconstruction and an age estimation for the studied level can be extrapolated from the obtained diagram.

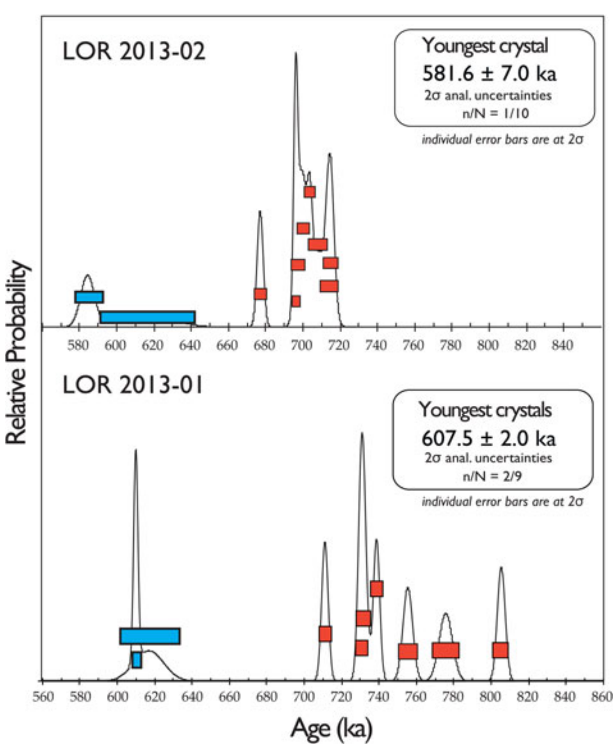

Figure 4. $^{40}Ar/^{39}Ar$ probability diagrams obtained for Loreto LOR 2013-01 and LOR 2013-02.

Revision of the lithic assemblage of layer A

The whole lithic assemblage stored for the lower Paleolithic layer A has been revised. To perform these studies, we used the common definition of the modes of debitage and flaking processes and we referred to the definition employed for middle Pleistocene sites in Europe (Rossoni-Notter et al., 2016; V. Villa et al., 2016; Moncel et al., 2020). The material integrated in this work is preserved at the National Archaeological Museum of Venosa (Basilicata, Italy). While conducting this study, special focus was paid to the description of the cores and flakes to better detail and characterize the core technologies (core types and sizes, removals organization, platforms, raw material shapes and natural forms, and, for the flakes, the removals, butts, shapes, and retouches). To carry out these new analyses, we referred to the works of Barral and Simone (1983, 1984) and Crovetto (1993) that already studied the typology of the main pieces (general sizes, raw material, categories, types of retouches).

RESULTS

Geochronology

$^{40}Ar/^{39}Ar$ on single grains

Results for the two samples are presented as probability diagrams (Fig. 4). Both probability diagrams are multimodal and demonstrate a very important reworking of various volcanic units. Except for two crystals from LOR 2013-01 and two others from LOR 2013-02, all the crystals analyzed are older than 670 ka (see Fig. 4), suggesting reworking of crystals corresponding to the earliest explosive activity of Mount Vulture volcano (Foggianello synthem; Giannandrea, 2006).

For LOR 2013-01 the two youngest crystals are centered around 607.5 ± 2 ka and for LOR 2013-02 the young crystal indicates an age of 581.6 ± 7 ka. These two ages cannot be considered as the depositional ages of the related sedimentary levels, but they can provide determinant geochronological information.

ESR

The results of the ESR analysis performed using the multicenter approach are displayed in Table 2. The equivalent doses determined from both aluminum and titanium–lithium centers are very homogeneous for the two sets of measurements and allow the calculation of a mean age of 340 ± 41 ka for deposition of this level, which is located at the top of the stratigraphic sequence of Loreto (close in elevation to the C level).

ESR/U-series

U-series and ESR/U-series data and ages are displayed in Tables 3 and 4, respectively. The U contents measured in the Loreto dental tissues are quite high, especially in tooth VL-854 in which they are higher than 11 ppm and 1000 ppm in the enamel and cementum tissues, respectively. Because these two tissues also display high $^{230}Th/^{234}U$ ratios, the internal dose rate contributions are consequently important and the corresponding ESR/U-series age is the youngest of the heterogeneous set of results, as showed by a

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Table 2. ESR data and ages of Loreto 2013-03 sediment. Data are expressed with one sigma (1σ) error range.

Sample, center, and run	D_α (μGy/a)	D_β (μGy/a)	D_γ (μGy/a)	D_{cos} (μGy/a)	D_a (μGy/a)	Water (%)	Bl (%)	D_e (Gy)	Ages (ka)
LOR 2013-03 Al 1	83 ± 5	1081 ± 53	903 ± 49	152 + 8	2219 ± 72	10 ± 5	51	764 ± 53	344 ± 41
LOR 2013-03 Al 2								756 ± 52	341 ± 40
LOR 2013-03 Ti 1							100	775 ± 82	349 ± 63
LOR 2013-03 Ti 2								741 ± 46	334 ± 35
								Mean age	**340 ± 41**

multimodal probability plot ranging from 293 ± 33 ka (VL-A854) to 480 ± 95 ka (VL-252), and leading to a quadratic weighted mean age of 344 ± 120 ka (2σ), which seems to be greatly underestimated despite its large uncertainty. These results seem to be greatly dependent on the U-uptake kinetics reconstructions, therefore in order to verify the validity of the dosimetric reconstruction, we tried to fit an isochron diagram for the Loreto LOR A teeth (Tables 3 and 4; Fig. 5). The VL-854 tooth seems definitively out of range in comparison with the three other teeth that show an excellent regression line fit ($R^2 > 0.99$), allowing the calculation of an isochron age around 561 ± 50 ka (2σ), which is in better agreement with the geological age estimation. This isochron diagram indicated that the paleodosimetric reconstruction seems well representative of the historical dose rate for these three teeth, which is in accord with Bahain et al. (2021).

Lithic assemblage of the archeological layer A

Barral and Simone (1983, 1984) and Crovetto (1993) totaled 528 artefacts in layer A. Globally, the material is fresh, covered sometimes by patches of breccia. The assemblage is composed of two groups of tools associated with cores: (1) heavy-duty tools that display a significant diversity of the raw material used; pebbles/cobbles on limestone (84%), sandstone (14%), volcanic rocks, quartzite/quartz (only 1%), and one in flint (c.f., Crovetto, 1990); and (2) light–heavy-duty tools (n = 156) made of various types of flint collected as small slabs or small nodules/pebbles in regard to the cortex. The flint is sometimes of bad quality with inclusions. The origin is possibly local, collected in situ for some according to Barral and Simone (1984) and Crovetto (1990).

Heavy-duty tools

This category totals 145 pieces (27% of the total) (Crovetto, 1993). Most of the series is composed of entire pebbles (n = 51), broken pebbles (n = 25), pebbles with a single removal (n = 15, hammerstones?), and pebble tools (n = 54). The selected pebbles are thick and short. The shaped part is diversified, pointed, and convex with many or some unifacial or bifacial removals. Some pebble tools could be described as chopper-cores based on the distribution of the removals (n = 4). There are also some thick "rabot" types and one unifacial pick (n = 4) Entire pebbles and pebble tools measure similar length (50–125 mm). Only one large cutting tool can be described as a biface or "proto-biface" (c.f., Barral and Simone, 1984) on a flint partially cortical flake (despite mainly small available flint nodules/slabs). It is shaped by some large and deep removals, without secondary retouches. The tool is irregular, asymmetrical, and has a curved cross-section (120–60–25 mm) (see Fig. 6).

Light–heavy-duty tools and core technology. The revision of the cores allows estimation of a total of 18 in flint and 10 on other stones (9 on limestone and one on quartzite). The flint cores are polyhedral, pyramidal, bipyramidal, Clactonian-type, and "atypical." The standardization is low with a large diversity of categories due to the limited number of removals. The debitage uses the natural shape of the raw material, with frequently a cortical platform and one main debitage surface. Possibly, three cores were made on a single large flake. For the cores in other raw materials, they are mainly with one debitage face or orthogonal with two surfaces made on a nodule or pebble side with abrupt centripetal removals (see Fig. 6).

The flint cores have an average size of 30–53 mm with a mean thickness of 20–30 mm. The limestone cores, which constitute the second most represented raw material, have an average length of ∼70 mm. Three flint cores are retouched.

The flake assemblage is made of short and thick flakes with a flat striking platform with open angles that are typical of the Clactonian-type debitage. The limestone flakes are often cortical and possibly constitute remains of pebble-tool façonnage. Many flint flakes carry either cortical patches or are without cortex with a back and centripetal removals.

Most of the flake-tools are in flint (94%). The other flakes, made in other materials, are not retouched. The series is composed of 156 flake-tools (including 147 on siliceous stones) and 185 unretouched flakes. The size range of the flake-tools is 50–70 mm, which is similar to the size of the unretouched flakes. The flake-tools are mainly scrapers opposed to a back, denticulates, notches, some points, and multiple tools with invasive, abrupt, and "scalariform" retouches. We noted some bifacial and direct-inverse retouches.

The hypothesis of the introduction on the occupation of material on flint has to be considered, which would make the 20 m^2 archeological layer that was excavated the record of "specialized occupations or activities." There are few flint cores compared to the number of flakes. The ratio of flake-tools is high, mainly made on flint. Pebble tools and an additional debitage could have been made in situ.

DISCUSSION

Dating of archaeological horizon A (LOR A)

To determine the age of the Lower Paleolithic level A, we applied three distinct geochronometers: the $^{40}Ar/^{39}Ar$ on single crystal laser fusion, the ESR/U-series on teeth, and the ESR on bleached quartz. Unfortunately, the $^{40}Ar/^{39}Ar$ results do not allow a direct age to be assigned to the sedimentary layers analyzed. Indeed, the probability diagrams obtained for both LOR 2013-01 and LOR

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Table 3. U-series and ESR data of the Loreto A teeth. Data are given with two sigma error range.

Samples	Tissue	U content (ppm)	$^{234}U/^{238}U$	$^{230}Th/^{232}Th$	$^{230}Th/^{234}U$	$^{222}Rn/^{230}Th$	Initial thickness (μm)	Removed thickness internal side (μm)	Removed thickness external side (μm)
VL-A252	cement	461.12 ± 1.20	1.347 ± 0.003	911	0.905 ± 0.006	0.257	977 ± 122	45 ± 6	30 ± 4
	dentine	327.80 ± 1.08	1.324 ± 0.003	> 1000	0.766 ± 0.006	0.298			
	enamel	3.096 ± 0.01	1.404 ± 0.005	350	0.756 ± 0.006	0.433			
VL-A655	cement	737.64 ± 2.79	1.279 ± 0.002	> 1000	0.986 ± 0.009	0.742	1003 ± 125	61 ± 8	42 ± 5
	dentine	490.10 ± 1.39	1.425 ± 0.003	> 1000	0.965 ± 0.007	0.284			
	enamel	5.55 ± 0.01	1.385 ± 0.004	> 1000	0.869 ± 0.005	0.479			
VL-A854	cement	1043.75 ± 3.55	1.122 ± 0.003	> 1000	1.073 ± 0.009	0.268	912 ± 114	36 ± 5	24 ± 3
	dentine	469.80 ± 1.60	1.375 ± 0.002	> 1000	0.931 ± 0.007	0.309			
	enamel	11.36 ± 0.02	1.169 ± 0.004	818	0.998 ± 0.010	0.442			
VL-A911	cement	126.93 ± 0.97	1.251 ± 0.004	549	1.052 ± 0.012	0.245	1004 ± 125	53 ± 7	76 ± 10
	dentine	201.84 ± 1.14	1.411 ± 0.005	> 100	0.925 ± 0.016	0.323			
	enamel	2.62 ± 0.01	1.392 ± 0.002	514	0.826 ± 0.004	0.433			

Table 4. ESR/U-series data and ages of the Loreto A teeth. Data are given with two sigma error range.

Samples	Tissue	D_E (Gy)	U uptake parameters p (regular) or *n* (*italics*)	D_a α internal (μGy/a)	D_a β (μGy/a)	D_a (γ + cosm) (μGy/a)	D_a total (μGy/a)	ESR/U-series ages US or AU models (ka)
VL-A252	cement	3631 ± 368	0.526 ± 0.133	400 ± 200	4625 ± 1684	2547 ± 437	7757 ± 1751	**480** ± **95**
	dentine		0.161 ± 0.293					
	enamel		0.241 ± 0.308					
VL-A655	cement	5078 ± 426	0.844 ± 0.053	1544 ± 514	8897 ± 2048	2547 ± 437	12988 ± 2156	**391** ± **58**
	dentine		0.799 ± 0.061					
	enamel		0.539 ± 0.108					
VL-A854	cement	5246 ± 476	*0.0049 ± 0.0069*	*2648 ± 37*	*12707 ± 286*	*2547 ± 437*	*17902 ± 523*	**293** ± **33**
	dentine		0.843 ± 0.040					
	enamel		*0.0046 ± 0.0069*					
VL-A911	cement	4510 ± 446	*0.0030 ± 0.0007*	*1005 ± 135*	*6690 ± 719*	*2547 ± 437*	*10242 ± 852*	**440** ± **72**

2013-02 highlight the reworking of numerous ancient volcanic events (see Fig. 4). However, the youngest juvenile crystal from LOR 2013-01, which was dated around 610 ka, ensures that archaeological level A is younger than this age. Interestingly, this age of 610 ka fits well within uncertainties of the reworked eruption evidence found at the top of the Notarchirico sequence (Pereira et al., 2015), corresponding in age to the San Michele or Ventaruolo subsynthems (see Table 1). The age of the young crystal dated in LOR 2013-02 (around 585 ka) is chronologically coherent with the last eruptive phase of the Monte Vulture supersynthem (Melfi synthem, see Table 1; Villa and Buettner, 2009). It is worth noting that neither probability diagram indicates occurrences of reworked eruptions from 680–615 ka associated with the Rionero (630 ± 20 and 714 ± 18 ka) and Toppo San Paolo (646 ± 7 and 673 ± 19 ka) subsynthems activities of the Monte Vulture supersynthem (see Barile Unit; Brocchini et al., 1994; Villa and Buettner, 2009).

While these activities are the ones mainly found within the Notarchirico stratigraphy (Piano Regio Formation of the Venosa basin, MIS 16), they are completely absent at Loreto. These results agree perfectly with the work of Lefèvre et al. (1999, 2010), who suggested, based on stratigraphy and tephrostratigraphy, that the Piano Regio Formation was fully eroded in the axial part of the basin. Lefèvre et al. (1999, 2010) consequently suggested that the Tufarelle Formation lies unconformably above the Fonte del Comune Formation (recording the Foggianello synthem volcanic activity deposits; see Table 1). Even if the $^{40}Ar/^{39}Ar$ data do not bring direct chronological constraints for level A, they provide an additional argument fitting well with the interpretation of Lefèvre et al. (2010) who suggested an age between about 484 ± 8 and 530 ± 22 ka (Case Lopes subsynthem).

The ESR age (340 ± 41 ka) that was calculated on bleached quartz from sample LOR 2013-03, collected at the top of the sequence, is altimetrically close to archaeological level C, which is constituted by evolved Acheulean industries. An age corresponding to the end of the Lower Paleolithic or to the beginning of the Middle Paleolithic is thus very possible. Unfortunately, the lack of data on the archaeological material of this level prevents a more thorough interpretation of this deposit. A reinvestigation of the site (archaeological and geological) would be needed to ensure the existence of a such human occupation during the MIS 9–11 period in Basilicata. This age also constitutes a minimum age for archaeological levels A and B.

The ESR/U-series ages obtained from the four teeth are all greatly underestimated due to the fundamental contribution of U-uptake kinetics. However, the isochron diagram obtained for three of the four dated teeth suggests an age for the teeth at 561 ± 50 ka (2s). This age suggests a MIS 13 (or the end of MIS 14) age for level A, which is in good agreement with Lefèvre et al., 2010, who proposed an age ranging between 484 ± 8 and 530 ± 22 ka. This is also in accordance with the previous interpretations of the paleontological assemblages that were correlated to the MIS 13 interglacial phase (Piperno et al., 1999).

Several things are needed if we want to improve the chronology of the various archaeological levels. Firstly, it would be essential to make new excavations on the original Loreto at Venosa site to test and/or sharpen the results obtained here. Secondly, it would also be very important to deeply study the chronology and geochemistry of the numerous synthems/subsynthems of Mount Vulture Volcano and correlate them with stratigraphies in the surrounding basins. Because the sites of Loreto at Venosa, Notarchirico, and Cimitero di Atella are unique testimonies of the emergence of the Acheulean and Lower Paleolithic occupations in southern Italy, it would be also crucial to provide detailed geochronological investigations of the sedimentary successions of the Venosa and Atella basins to provide accurate correlations between sites. As demonstrated in numerous previous studies (Marra et al., 2016; V. Villa et al., 2016; Pereira et al., 2017, 2020), tephrochronology is a very powerful tool for synchronizing archaeological, paleontological, paleoenvironmental, and/or paleoclimatic records. This improvement of knowledge regarding the eruptive history of Mount Vulture will be an essential point to understand the emergence and expansion of the Acheulean in this key area of Europe.

Loreto lithic strategies in the MIS 13 framework

Loreto's assemblage has been described as Early Tayacian and compared to assemblages from Baume–Bonne (France), Isernia

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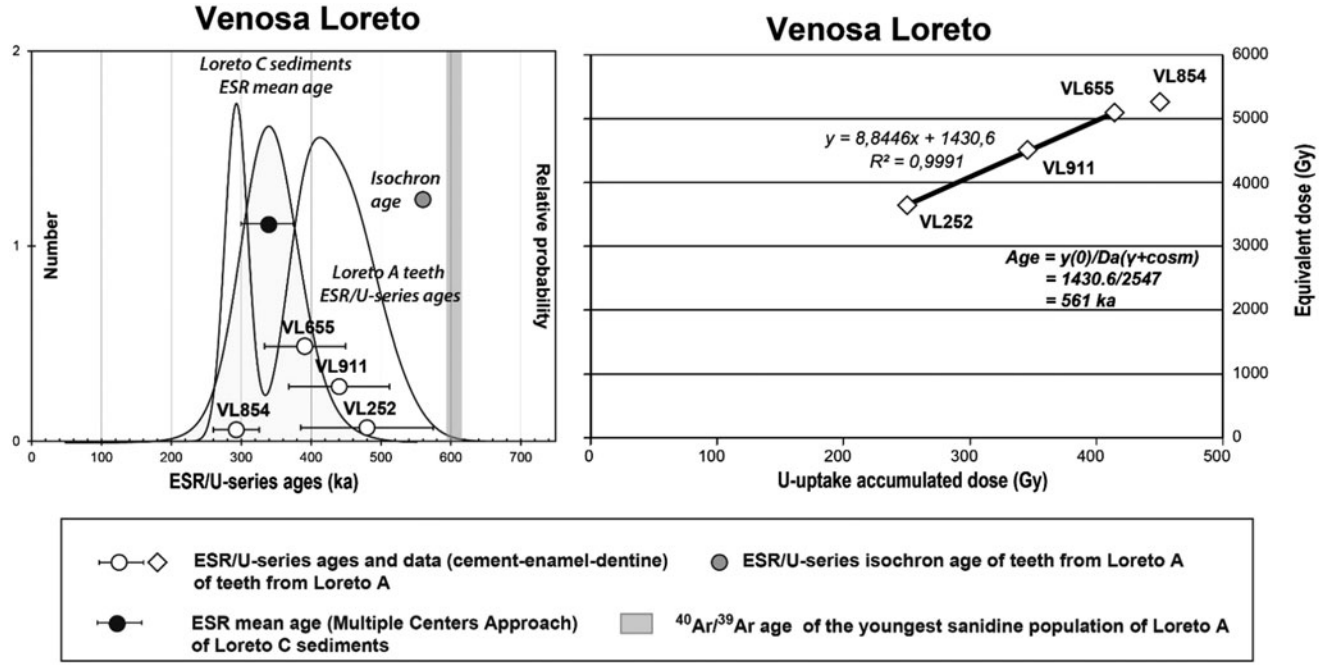

Figure 5. Age density probability plots (left, built using Isoplot 3.0 software, Ludwig, 2003) and isochron plots (right) obtained for the Loreto samples. The U-uptake accumulated dose corresponds to the sum of the internal (enamel) and beta dose (corresponding to dentine and cement) reconstructed for the considered sample along its entire geological history from the modeled uptake parameters.

la Pineta (Italy, unit T3c), or Notarchirico (Di Cesnola and Mallegni, 1996; Piperno et al., 1998; Grifoni and Tozzi, 2006) despite the poor knowledge about their ages. The Tayacian culture has been defined by the description of "Tayac" points and above all by the occurrence of invasive abrupt and stepped retouches on flake-tools (Henri-Martin, 1954; de Lumley, 1960) associated with denticulates, notches, and becs. Another main point relies on the scarcity of bifaces within the related assemblages.

Considering the attribution of archeological layer A to the interglacial MIS 13, our objectives are now to understand the place of this assemblage within the MIS 13 framework in Western Europe. The names and locations of the MIS 13 sites from Western Europe and of the other sites cited in the text are reported Figure 7. The European archeological data published so far for these sites are relatively diversified (core technologies, flake-tools, and ratio of bifaces). This is due either to traditions

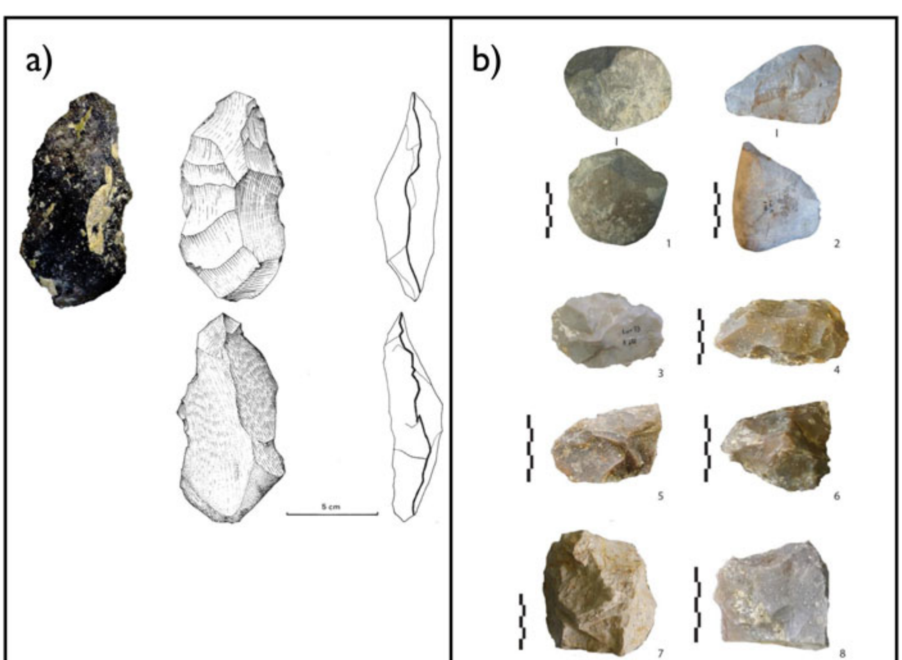

Figure 6. Examples of the industries from layer A at the Venosa Loreto site. (a) "Proto-biface" in flint; (b) 1, 2: Limestone pebble tools with abrupt removals; 3: flint flake-tool with peripheral denticulates retouch; 4: flint peripheral scraper with a scaled retouch; 5, 6: flint "déjeté" points with a few invasive retouches; 7: limestone unifacial core with crossed removals; 8: flint core with peripheral and abrupt removals. Drawing from G. Vicino in Barral and Simone, 1984; photo by M.-H. Moncel.

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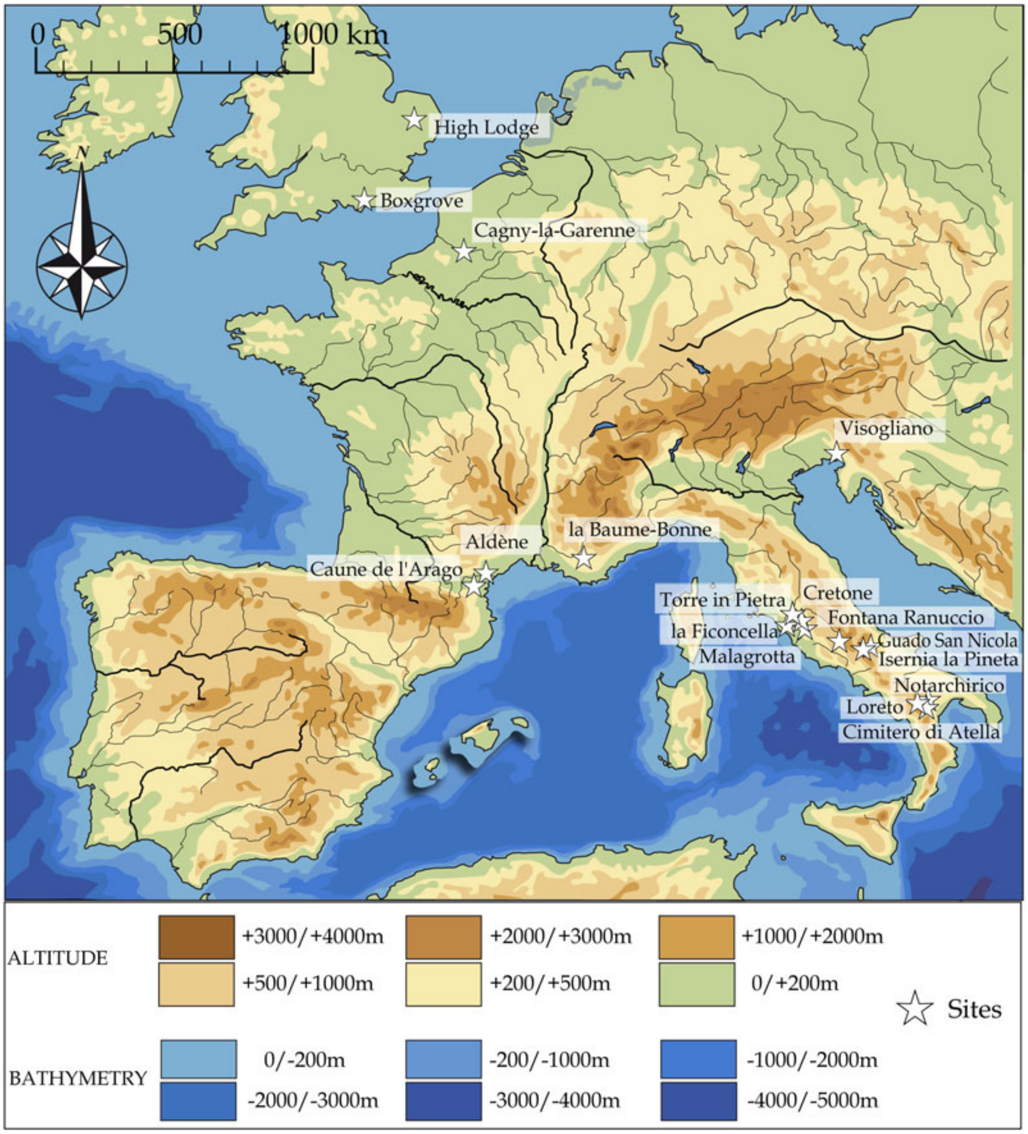

Figure 7. Locations of key European Paleolithic sites for the period investigated.

or to specific activities. To ensure the accuracy of our techno-lithic comparisons between the Loreto assemblage and other sites it is necessary to focus on sites: (1) that are, like Loreto, located in a context of diversified available raw materials; and (2) for which we can observe common features.

One of the apparently suitable Lower Paleolithic sites is the one of Fontana Ranuccio located in Central Italy (Anagni basin) that has been recently dated to the period contemporaneous of the MIS 11 interglacial (Pereira et al., 2018). Indeed, both sites are characterized by a small-size shaping and debitage interconnected and by a diversity of light-duty tools component. In other close sites, from the Roman province dated to MIS 11 (Torre in Pietra [level m], Malagrotta) and MIS 13 (Cretone, Osteria Moricone) the debitage is made of small cores with few bifaces associated to many and diversified flake-tools (Ceruleo et al., 2015, 2019; P. Villa et al., 2016, 2021; Marra et al., 2022).

The site showing the closest lithic assemblage to Loreto is the MIS 13 site of Visogliano, which is located in the north of the Italian peninsula (see Fig. 7). Indeed, a diversity of stones as well as the presence of core technologies and two partial bifacial tools/cores have been documented at Visogliano (Falguères et al., 2008). Likewise, at Aldène, France (levels possibly at the end of MIS 13), the series is composed of many pebble-tools, evidence of Clactonian-type flaking (Ashton et al., 1992; Rossoni-Notter et al., 2016), and thick flake-tools. At Caune de l'Arago (unit II, MIS 13, levels H, I, J), in a context of seasonal occupations, the series did not yield bifaces, but there are many pebble-tools on quartz and the gathering of good-quality stones in a perimeter of 5–30 km. There is a complex debitage on the good-quality stones, simpler on quartz with some evidence of Clactonian-type debitage. The retouch of flake-tools is often abrupt and thick (Barsky, 2013).

For northwestern of Europe, in a context of main flint use, MIS 13 sites are characterized by the presence (or not) of bifaces inducing diverse pene-contemporaneous traditions. At High Lodge, for example, bifaces are totally absent, while at Boxgrove and Cagny-la-Garenne, bifaces compose the series in various proportions (Ashton et al., 1992; Lamotte and Tuffreau, 2001; Garcia-Medrano et al., 2019). The debitage is mainly unipolar or Clactonian-type, even if some evidence of more complex core technology exists (e.g., Levallois-type; Moncel et al., 2021). Flake-tools are diverse and mainly of large size, composed of scrapers (large and invasive retouches at High Lodge), denticulates, and notches.

A deeper analysis of the material of Loreto, including micro-wear study, raw material identification, and detailed knowledge of the technological strategies is necessary to better characterize MIS 13 human strategies in southern Europe, before the long glacial event of MIS 12 recorded a behavioral shift.

CONCLUSIONS

The Basilicata region is known for hosting three major Lower Paleolithic sites associated with the emergence and diffusion of the Acheulean culture in Europe: Notarchirico, Cimitero di Atella, and Loreto. However, the site of Loreto was never dated directly before the present study, thus making its comparison with other sites tenuous. In this contribution, we applied three absolute dating methods relying on distinct physical principles to date the Lower Paleolithic level A of Loreto. The techniques applied (ESR/U-series, ESR, and $^{40}Ar/^{39}Ar$) provided complementary results, which allowed us to propose a MIS 13 age for this level, in agreement with the geological and paleontological works published more than ten years ago. Re-study of the lithic material kept in the collections of the National Archaeological Museum of Venosa, combined with a better-known chronological context, allowed comparisons of the Loreto records within the rare MIS 13 data in Western Europe. While technical similarities are similar to other European MIS 13 sites such as Visogliano (Italy) or Aldène (France), deeper analyses of the material of Loreto are needed and would contribute to better characterize MIS 13 human strategies in southern Europe.

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