

The first Large Flake Acheulean in Europe at Revilla de Valparaíso site, Hortigüela, Spain

Francisco-Javier García-Vadillo^{a,b,c,*}, Eudald Carbonell^{b,a,c},
Xosé-Pedro Rodríguez-Álvarez^{b,a}, Alfonso Benito-Calvo^d, Régis Braucher^e,
Davinia Moreno^d, Isabel Hernando-Alonso^d, Rodrigo Alonso-Alcalde^{f,g},
Marta Navazo-Ruiz^g, Antoni Canals-Salomó^{b,a,c}

^a Institut Català de Paleoeologia Humana i Evolució Social (IPHES-CERCA), Zona Educacional 4, Campus Sescelades URV (Edifici W3), Tarragona, 43007, Spain

^b Departament d'Història i Història de l'Art, Universitat Rovira i Virgili (URV), Avinguda de Catalunya 35, Tarragona, 43002, Spain

^c Equipo Primeros Pobladores de Extremadura, Casa de la Cultura Rodríguez Moñino, Avenida Cervantes s/n, Cáceres, 10003, Spain

^d Centro Nacional de Investigación sobre la Evolución Humana (CENIEH) (Burgos, Spain), Paseo Sierra de Atapuerca 3, Burgos, 09002, Spain

^e Aix-Marseille Univ, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, 13545, France

^f Museo de la Evolución Humana (MEH), Paseo Sierra de Atapuerca s/n, Burgos, 09002, Spain

^g Universidad de Burgos, Paseo Comendadores s/n., Burgos, 09001, Spain

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ABSTRACT

Revilla de Valparaíso (Hortigüela, Burgos, Spain) is a Large Flake Acheulean (LFA) lithic assemblage on the Iberian Peninsula that is crucial for understanding the technical traditions on which the European Acheulean in the Early Middle Pleistocene was founded. These lithic industries were discovered in an alluvial deposit that has been dated to 696 ± 32 ka (MIS 17), using Terrestrial Cosmogenic Nuclides (680 ± 60 ka) and Electron Spin Resonance on quartz (702 ± 32 ka), and forms the base of a higher degraded terrace, whose strath is currently preserved at +29–30 m above the River Arlanza (Duero basin). It is a strategic location that conserves a quartzite lithic assemblage with large cutting tools (LCTs) frequently knapped on flakes. Their affinity with LFA traditions and chronology suggests that: 1) around 700 ka, throughout Western Europe, there were populations that developed a heterogeneous Acheulean that subsequently became regionalised (MIS 12); 2) the Acheulean of the Iberian Peninsula with diversified LCTs, frequent use of large flakes to shape handaxes, and possibly cleavers, is earlier than 500 ka, closely related to the LFA and contemporary with North African Acheulean sites; and 3) MIS 19 (790–761 ka) was key in the processes that consolidated western European settlement by groups with heterogeneous technological traditions.

1. Introduction

The question of whether there was a single ancient Acheulean cultural tradition in Western Europe remains to be answered. The Revilla de Valparaíso archaeological site (Hortigüela, Burgos, Spain) (Fig. 1) provides relevant chronological and technological data on the ancient Acheulean technological traditions that were the foundation, at Marine Isotope Stage 16 (MIS 16) (Lisiecki and Raymo, 2005), for the cultural phenomenon of the European regional Acheulean after MIS 12 and the Mid-Brunhes Event (MBE) (Moncel et al., 2020b, 2022; Moncel and Ashton, 2018).

The earliest Acheulean technical traditions in Western Europe (Fig. 1), defined in terms of shared technological choices and toolkits, appeared in MIS 16 (Moncel et al., 2019, 2020a). These traditions emerged following: 1) an Acheulean episode prior to MIS 19, as identified at the Barranc de La Boella site (960–781 ka, MIS 25–MIS 19) (Vallverdú et al., 2014); and 2) a possible occupational hiatus (MIS 19–MIS 16) that could be related to a more extensive demographic crisis (MIS 22–MIS 20) (Hu et al., 2023; Key, 2024; Mosquera et al., 2013; Muttoni and Kent, 2024; Ollé et al., 2016). The available data (Fig. 1) suggest that the end of this occupational hiatus was characterised by two major technical traditions that appeared in two distinct areas at two

* Corresponding author. Institut Català de Paleoeologia Humana i Evolució Social (IPHES-CERCA), Zona Educacional 4, Campus Sescelades URV (Edifici W3), 43007, Tarragona, Spain.

E-mail address: garciafvadillo@gmail.com (F.-J. García-Vadillo).

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different points in time (MIS 16 and MIS 13). In this complex scenario, the Pyrenees acted as a geographical boundary delineating the extent and influence of the North-Pyrenean and Large Flake Acheulean (LFA) technical traditions (Moncel and Ashton, 2018; Santonja and Pérez-González, 2010; Santonja and Villa, 2006; Sharon, 2010; Tuffreau et al., 2008). These influences can be seen in the technological affinities of the heterogeneous European regional Acheulean in the territories on the northern and southern sides of the Pyrenees (Bordes, 1950, 1966, 1984; Chevrier, 2006; López-Recio et al., 2018b; Méndez-Quintas et al., 2020; Mourre and Colonge, 2016; Santonja and Pérez-González, 2010; Santonja and Villa, 2006; Tuffreau et al., 2008; Turq, 2000).

In the northern Pyrenees region (Fig. 1), at the boundary of the Middle Pleistocene Transition (MIS 16), the lithic industries documented at the Moulin-Quignon, La Noira and Notarchirico sites (and possibly Bois-de-Riquet-US4) illustrate the emergence of novel technical traditions, which appear to have come from the Balkan region (Antoine et al., 2019; Bourguignon et al., 2016; Moncel et al., 2013, 2020b; Piperno et al., 1998; Viallet et al., 2022). Without crossing the Pyrenees, these groups remained in northern latitudes during the cold conditions of MIS 16, developing the technical traditions of the North-European Acheulean (Moncel et al., 2022; Moncel and Ashton, 2018; Tuffreau et al., 2008).

South of the Pyrenees (Fig. 1), following the discovery of stone tools in Gran Dolina-TD8 (Mosquera et al., 2024), the occupational hiatus observed on the Iberian Peninsula starting in MIS 19 is now believed to have ended in MIS 15. It seems Iberia was not a climatic refuge during MIS 16 (Moncel et al., 2022) and some researchers consider a North-Pyrenean origin for the populations involved in the reappearance of the Acheulean after the La Boella episode (Key, 2024). In contrast to these ideas, the large cutting tools (LCTs) (Kleindienst, 1962) from the Sima de los Huesos and Gruta da Aroeira sites (Carbonell and Mosquera,

2006; Daura et al., 2017), and possibly Galería-Gila if other more recent MIS 9 dates are not considered (Demuro et al., 2014; García-Medrano et al., 2015), suggest that the Acheulean reappeared later. In the Iberian Peninsula, the available data indicate that MIS 13 comprises the oldest known evidence of the LFA with North African analogies (García-Medrano et al., 2014; García-Vadillo et al., 2023; Méndez-Quintas et al., 2020; Santonja and Villa, 2006; Sharon and Barsky, 2016). The Iberian Acheulean industries are distinguished by: 1) their affinity with LFA technical traditions, as evidenced by the frequent presence of cleavers and the shaping of handaxes on flakes; and 2) the absence of these technical similarities in the northern Pyrenees region, with the exception of nearby areas to the north of the Pyrenees.

It appears that the LFA was not part of the ancient Acheulean traditions of Western Europe (Bourguignon et al., 2016; Moncel et al., 2019, 2020b, 2022) and its influence remained geographically confined to southwestern Europe during more recent stages (<MIS 15) (Gallotti, 2015; Méndez-Quintas et al., 2020; Mourre, 2003; Santonja and Villa, 2006; Sharon, 2010, 2011; Sharon and Barsky, 2016). In the Iberian Peninsula, there is no data that can be used to substantiate the existence of LFA industries prior to MIS 13. Nevertheless, some researchers have considered this region as a potential route by which the Acheulean entered Europe (Alimen, 1975; Freeman, 1975; García-Vadillo et al., 2023; Giles Pacheco and Santiago Pérez, 1987; O'Regan, 2008; Santonja and Villa, 2006; Souville, 1983). To date, the absence of numerical dating has hindered precise determination of the age of the Acheulean from the middle-higher Iberian river terraces (Giles Pacheco et al., 2000; Rodríguez de Tembleque et al., 2010; Rubio-Jara et al., 2016; Santonja and Pérez-González, 2001).

The lithic industry and numerical dating of the Revilla de Valparaíso site challenge: 1) the idea that the Early Acheulean technical traditions that arrived in Western Europe in MIS 16 represent culturally

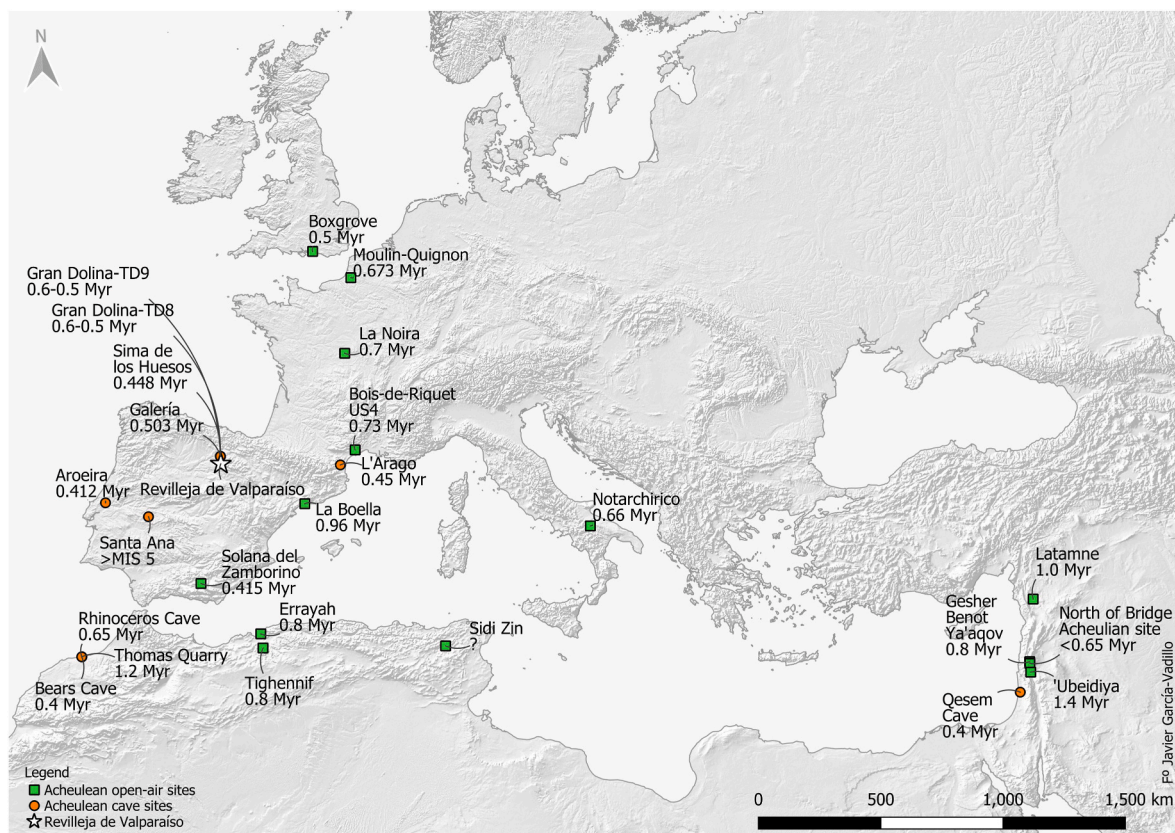


Fig. 1. Location of the Revilla de Valparaíso site in the Early Acheulean context in the Mediterranean area: sites and mean dates. The oldest dated Acheulean industries and other Middle Pleistocene evidence of human activity are shown in the Iberian Peninsula. Figure created using QGIS-3.40.10 'Bratislava' (<https://qgis.org/>). (F.-J. García-Vadillo).

homogeneous groups (Antoine et al., 2019; Bourguignon et al., 2016; Moncel et al., 2020a, 2020b; Piperno et al., 1998); and 2) the notion that the LFA traditions that led to the Iberian Peninsula's singular Acheulean and the cultural phenomena of technological multiplicity arrived late (MIS 14-MIS 13) via the Strait of Gibraltar (Barsky et al., 2021; Carbonell et al., 2016, 2018; García-Vadillo et al., 2023; Giles Pacheco et al., 1996; Méndez-Quintas et al., 2018; Santonja and Villa, 2006; Sharon, 2006, 2011; Sharon and Barsky, 2016).

2. Revilleja de Valparaíso site: territorial, geomorphological and stratigraphic settings

Revilleja de Valparaíso (ETRS89/UTM Zone 30N: 465715; 4657296; 949 m asl) is located on the northeastern edge of the Northern Plateau of the Iberian Peninsula (Fig. 2a and b). It is situated on the Mesozoic edge of the Sierra de la Demanda, which forms a natural border between the Ebro and Duero basins. Its location on the Cerro de la Revilleja is at a strategic point at the confluence of the Valparaíso and Arlanza rivers, tributaries of the Duero River (Fig. 2c). Two natural routes converge here: east-west (the Arlanza River) and northwest-southeast (the Valparaíso River), as do the limits of the ecosystems of the gorges in the Mamblas and Gayubar mountain ranges, crossed by the canyon created by the Arlanza (Fig. 2c and d). The routes linking the inland territories of the Sierra de la Demanda and the headwaters of the Duero River to the Northern Plateau pass through this area (Fig. 2b). The location also connects the western edge of the Sierra de la Demanda, including the Sierra de Atapuerca, to the corridors between the Ebro and Duero basins.

The site is located on the hummocky hill of La Revilleja (Fig. 3a). The upper part of the hill comprises rounded gravel remains lying on bedrock of the Lower Cretaceous, with outcrops of this bedrock at various points. These are the remains of a degraded fluvial terrace, now 29–30 m above the modern riverbed (Fig. 2d). The terraces of the River Arlanza in this area have received scant attention, although downstream there are up to 17 defined levels (T1_{AZA} +121–130 m) (Benito Calvo, 2004), some of which have been dated (Table 1).

Archaeological work undertaken to determine the stratigraphic origin of the lithic artefacts previously recovered from an area of approximately 0.5 ha on the surface of the slopes and the lower part of La Revilleja Hill took into account its topographic configuration (Fig. 2). Surveys located additional lithic artefacts on the surface at the same locations where they had previously been recovered. Meanwhile, seven trenches were mechanically excavated in the lower, middle, and upper parts of the hill to document the preserved sedimentary processes. The results indicated that the highest part of La Revilleja Hill was the most suitable location for a archaeological excavation to recover relevant information about the original context of the previously found lithic artefacts. The two excavation areas established at the highest point of the hill (Test Pits 1 and 2; approximately 40 m²) yielded contextualised archaeological information from the preserved sedimentary outcrop overlying the Cretaceous bedrock. The maximum excavation depth of 1.40 m was reached in a limited area of Test Pit 1, approximately 50 cm below the base level reached in both test pits (~0.90 m).

The sedimentary sequence containing archaeological material at the top of the hill is a low thickness (~1–2 m) alluvial fill of a fluvial terrace (Fig. 3a2 and b2, and Supplementary Fig. S 1). These deposits comprise pebble- and cobble-sized gravels, with boulders in places, mostly sub-rounded and clast-supported, of quartzite composition, and other metamorphic rocks, with a massive appearance or coarse stratification and local signs of imbrication structures. The matrix between the gravels consists of medium to coarse sands and clays. The grey colours of the upper 30–40 cm in some areas and the upper 20–30 cm in other points of the two test-pit areas (see Figs. 3 and 4), correspond to an A soil horizon developed in a clast-supported gravels deposit with a significant content in organic matter. On the other hand, the lower part of the sedimentary sequence contains also mainly clast-supported massive gravels, but with a high abundance of argillic matrices of red and, to a lesser extent,

greenish tones. This matrix indicates that the fluvial deposit is affected by clay illuviation and gley processes (saturation with stagnant water), indicating a Btg soil horizon.

The boundary between the upper and lower gravel deposits is sinuous, as suggested by the thickness of the A soil horizon developed in the upper clast-supported gravel deposit. The lower gravel bed overlies the Lower Cretaceous bedrock, locally formed by clays and, to a lesser extent, sands. The archaeological material from this alluvial fill was found at the lower part of clast-supported gravels (upper gravels, $n = 3$) and in the upper part of the lower clast-supported massive gravels affected by clay illuviation and gley processes (Btg horizon, $n = 10$) (Fig. 3a2, b1 and b2, and Supplementary Table S 1 and Fig. S 1).

On the slopes of the hill, at the foot of the terrace, colluvial material eroded from the terrace is present (Fig. 3a). This colluvium, measuring less than 1 m thick, rest directly on the Cretaceous bedrock. Lithic industry has been also identified in the sediments and on the surface of this colluvium; however, all of these lithic elements are considered surface findings, without stratigraphic context (see Appendix A. Supplementary material, 5.2.2 Organisation of surface collections of lithic materials).

3. Materials and methods

3.1. Materials

3.1.1. Lithic assemblage

Archaeological surveys, test pits and digs conducted in an area of ~0.5 ha around Cerro de la Revilleja (Fig. 2d) revealed the presence of lithic industry in the alluvial sedimentary sequence at the top of the hill and on the surface and colluvium of its slopes. Only the lithic industries found in the alluvial sedimentary sequence support the characterisation of the Revilleja de Valparaíso lithic assemblage (Figs. 3 and 4). The other lithic materials found on the surface and in the colluvium are devoid of any stratigraphic context.

The two test pits, located at the top of the hill, with a surface area of ~40 m² and a depth of ~140 cm, yielded a total of thirteen lithic artefacts, which were found imbricated between clasts and distributed over a sedimentary stretch ~40 cm thick (Figs. 3 and 4, and Supplementary Table S 1 and Fig. S 1). Some lithic artefacts ($n = 3$) were found at the bottom of the upper clast-supported gravels (Upper Gravels), at a depth of around 20 cm from the control elevation, whereas most of the lithic assemblage ($n = 10$) was found in the upper part of the lower gravel layer containing the Btg horizon (Lower Gravels-Btg horizon).

The lithic objects recovered from the Lower Gravels-Btg horizon (–20 to –60 cm below the control elevation) exhibit a clustered vertical distribution in three main depth groups: 1) –20 cm ($n = 1$); 2) –26 to –34 cm ($n = 5$); and 3) –50 to –59 cm ($n = 4$). The –20 cm depth corresponds to the upper boundary of the Lower Gravels-Btg horizon. The other two groups were recovered within intervals of less than 9 cm, and the vertical distance between them is 15.9 cm (Figs. 3 and 4).

The presence of slightly rounded edges and ridges in all these lithic artefacts, in addition to sparse surface abrasion that is sometimes more intense, suggests the action of fluvial sedimentary agents (Figs. 3, 4, and 7). It is notable that only the surface lithic materials of sub-assemblage 2 exhibit alterations of this kind (see Appendix A. Supplementary material, 5.2.2 Organisation of surface collections of lithic materials).

3.1.2. Sediment samples

The seven sediment samples used to determine the site's age by Terrestrial Cosmogenic Nuclides (TCN, six samples) and Electro Spin Resonance dating (ESR, one sample) analysis were obtained from the base of the lower clast-supported massive gravels layer (Lower Gravels-Btg horizon) containing most of the lithic industry assemblage (Figs. 3 and 4, and Supplementary Fig. S 1; coordinates are provided in the Supplementary Table S 1). To eliminate potential contamination from sedimentary particles introduced by roots or archaeological excavation, the dated samples were collected at a depth between –105 cm and –123

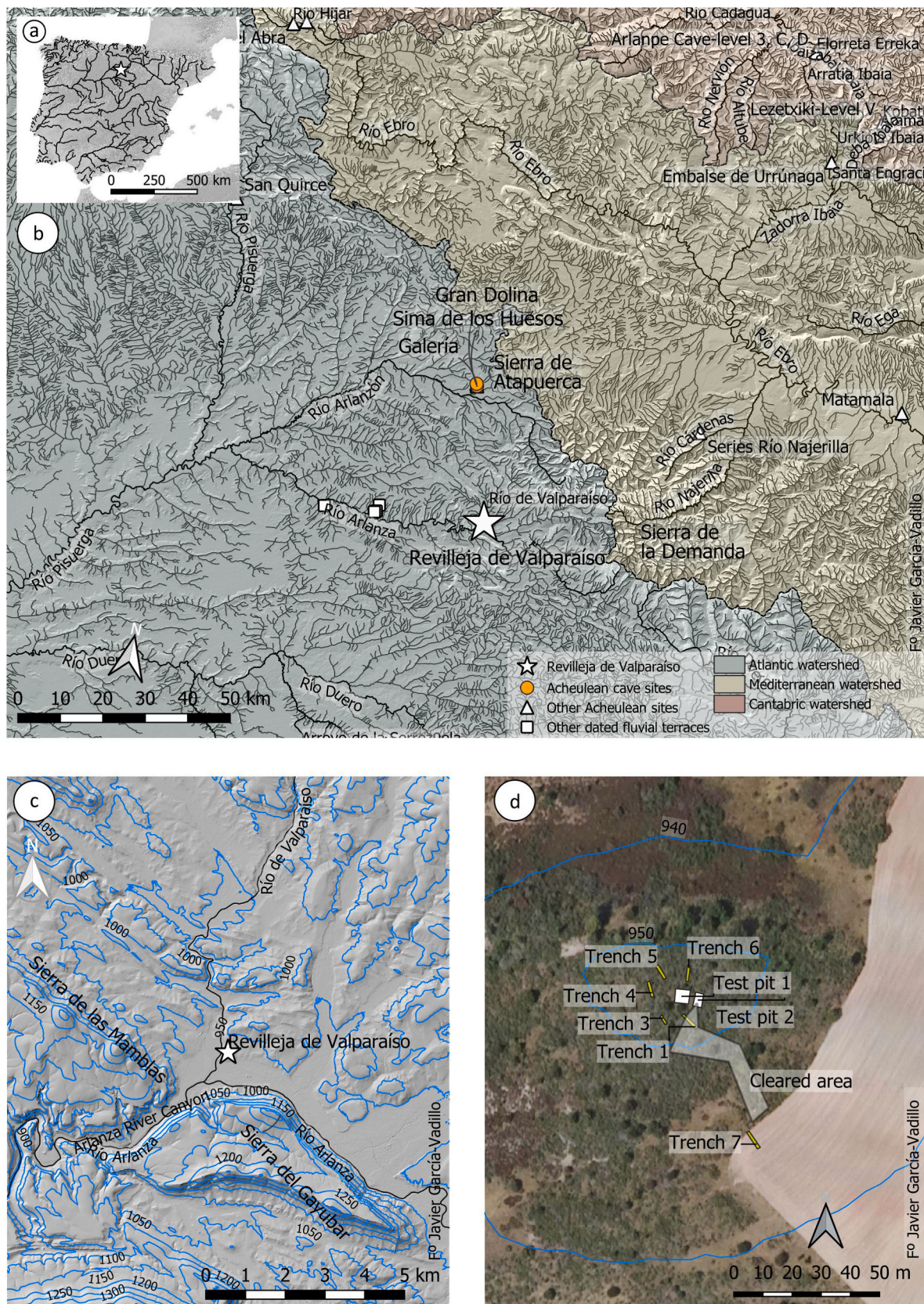


Fig. 2. Location of Rvilleja de Valparaíso: a) on the edge of the Northern Plateau of the Iberian Peninsula; b) on the border of the Duero and Ebro basins; c) at the confluence of the rivers Arlanza and Valparaíso; and d) at the top of La Rvilleja hill showing the distribution of the test pit areas and trenches around the hill. Figure created using QGIS-3.40.10 'Bratislava' (<https://qgis.org/>), cartographic base obtained from the Instituto Geográfico Nacional de España (www.cenig.es). (F.-J. García-Vadillo).

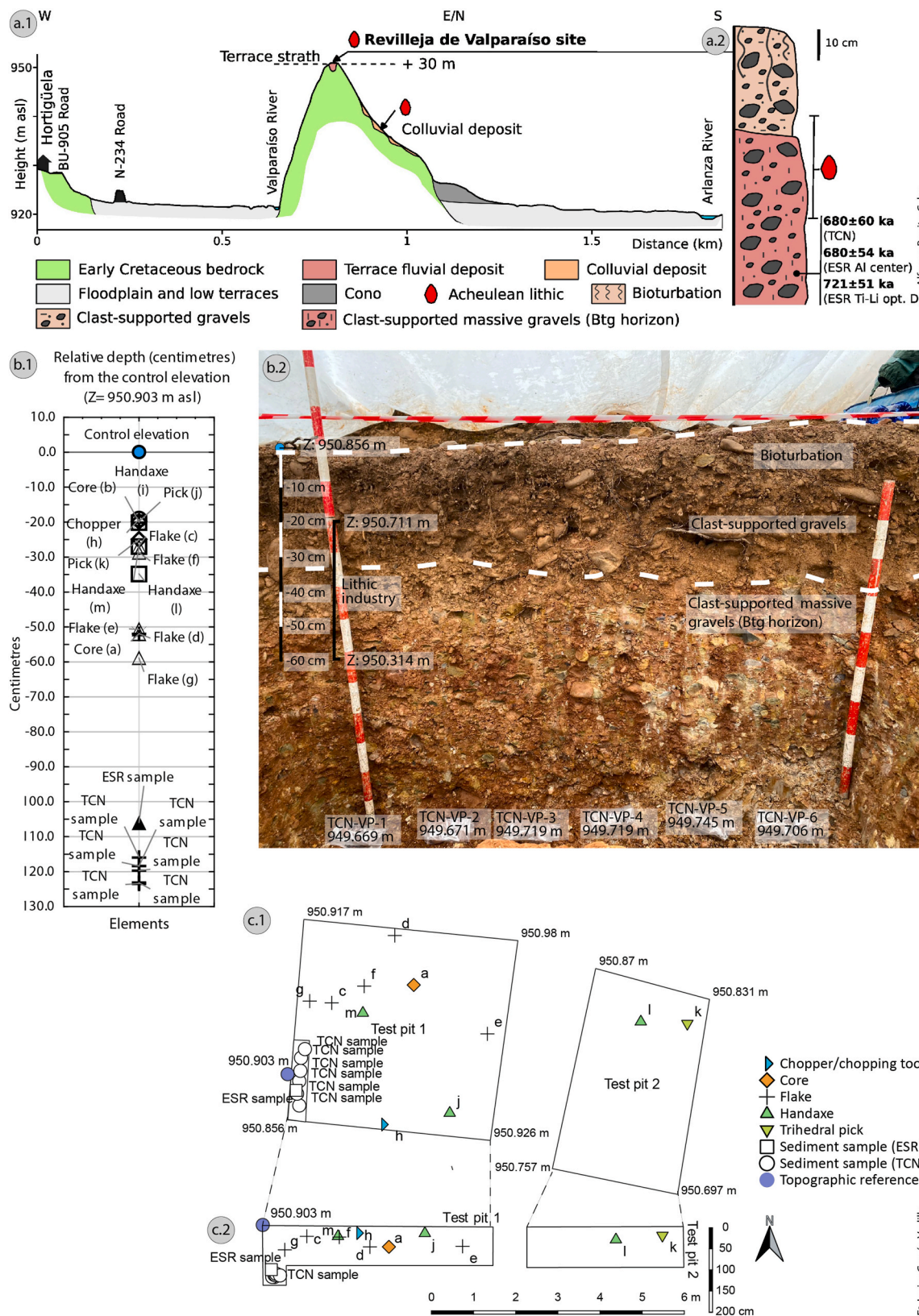


Fig. 3. Geomorphological (a.1) and stratigraphic (a.2) features of the Rivilleja de Valparaíso site, indicating the depths of the Acheulean lithic remains and dated sediment samples (b.1), shown beside and overlaid on a detailed view of the outcrop (b.2) showing the boundaries of the identified sedimentary layers (dashed lines). Horizontal (c.1) and transverse (c.2) projections of lithic remains and sediment samples are shown for the two test pits at the top of the hill. A detailed list of georeferenced items is provided in [Supplementary Table S 1](#). The alphabetic code (letter) assigned to the lithic artefacts is the same as that used in [Figs. 4 and 7](#). Figure created using QGIS-3.40.10 'Bratislava' (<https://qgis.org/>) and Inkscape-1.4 (<https://inkscape.org/>). (F.-J. García-Vadillo and A. Benito-Calvo).

Table 1

Dates obtained in the Arlanza and Arlanzón river terraces and other tributaries of the Duero. The ages of the Duero terraces correspond to intervals obtained from samples taken at different depths.

River	Date (ka)	Method	Reference
Arlanza River			
T5 +73-79 m	790 ± 220	ESR-AI	Moreno (2011)
T6 +64-67 m	700 ± 140	ESR-AI	Moreno (2011)
T10 + 33-36 m	350 ± 80	ESR-AI	Moreno (2011)
T13 + 12-17 m	230 ± 60	ESR-AI	Moreno (2011)
T14 +2-3 m	4.8 ± 0.3	TL	Benito-Calvo et al. (2008)
Arlanzón River			
T3 +70-78 m	1070-990	Magnetostratigraphy	Benito-Calvo et al. (2008)
T4 +60-67 m	990-780	Magnetostratigraphy	Benito-Calvo et al. (2008)
T5 +50-54 m	780-125	Magnetostratigraphy	Benito-Calvo et al. (2008)
T8 +35-37 m	400 ± 90	ESR-AI	Moreno et al. (2012)
T9 +30 m	348 ± 16	OSL	Arnold et al. (2013)
T9 +28-32 m	370 ± 70	ESR-AI	Moreno et al. (2012)
T11 + 12-13 m	115 ± 12	TL	Benito-Calvo et al. (2008)
Tera River			
T +30-35 m	342 ± 27	TT-OSL & pIR-IRSL ₂₂₅	Demuro et al. (2024)
T +16–20 m	237 ± 23; 242 ± 21	TT-OSL & pIR-IRSL ₂₂₅	Demuro et al. (2024)
Tormes River			
T +50 m	323 ± 19	pIR-IRSL ₂₂₅	Demuro et al. (2024)
T +34 m	252 ± 23	TT-OSL & pIR-IRSL ₂₂₅	Demuro et al. (2024)
T +14 m	244 ± 19	TT-OSL & pIR-IRSL ₂₂₅	Demuro et al. (2024)
T +8 m	219 ± 19	TT-OSL & pIR-IRSL ₂₂₅	Demuro et al. (2024)
Pisuerga River			
T9 +20-23 m	300-238	TT-OSL	Terradillos-Bernal et al. (2023)
Esla River			
T +95-100 m	970-510	TCN	Schaller et al. (2016)
T +76-78 m	720-320; 720-390	TCN	Schaller et al. (2016)
T +32-64 m	240-120	TCN	Schaller et al. (2016)
T +20-22 m	240-120	TCN	Schaller et al. (2016)
T +7-8 m	120-70	TCN	Schaller et al. (2016)
Duero River			
T3 +112–107 m	2270->550; 980->450	TCN	Rodríguez-Rodríguez et al. (2020)
T6 +85–81 m	2210->550; 610-450	TCN	Rodríguez-Rodríguez et al. (2020)
T10 + 39–34 m	1080-550; 330-250	TCN	Rodríguez-Rodríguez et al. (2020)
T11 + 26–22 m	550->150; 170->120	TCN	Rodríguez-Rodríguez et al. (2020)
T12 + 13–11 m	220-150; 140-120	TCN	Rodríguez-Rodríguez et al. (2020)
Duero River			
T3 +48-53 m	>230-360	OSL	Cunha et al. (2019)
T2 +27-32 m	57	OSL	Cunha et al. (2019)
T1 +13-17 m	39-12	OSL	Cunha et al. (2019)

cm, approximately 50 cm below the lowest recovered lithic artefact. For this purpose, a small test trench (~2 m²) was excavated within a delimited sector of Test-pit 1, from –80 cm to –130 cm depth, and the exposed section was cleaned prior to sampling.

3.2. Methods

3.2.1. Geospatial data acquisition

The geolocation data for the archaeological intervention areas, lithic artefacts, sediment samples and relative altitude of the sedimentary outcrop on the Valparaíso and Arlanza riverbeds were acquired using high-precision topographic instruments. A Leica GS15 GNSS GPS receiver operating in Real-Time Kinematic (RTK) mode was employed connected to the Virtual Reference Station (VRS) network of the Junta de Castilla y León, achieving coordinates with an accuracy of 1-2 cm. A Leica TS15 robotic total station was also utilised, employing a local topographic network with three reference points, enabling the acquisition of coordinates with millimetre precision. The coordinates of the reference network were established with the Leica GS15 GNSS GPS receiver using a 1.8 m antenna and GNSS measurements for 50 observations epochs until accuracies between 1.1 cm and 1 cm were achieved. The coordinate reference system employed is identified as ETRS89/UTM Zone 30N. The heights of the coordinates were corrected based on the EGM08REDNAP geoid of the Instituto Geográfico Nacional de España (IGN).

3.2.2. Dating methods

3.2.2.1. Terrestrial Cosmogenic Nuclides (TCN) dating method. *In-situ* produced cosmogenic nuclides are elements accumulated in a mineral exposed on the Earth's surface by interactions with secondary particles arising from the flux of cosmic rays. Minerals from freshly surface exposed to cosmic rays will accumulate cosmogenic nuclides at a rate depending on the site situation (latitude, longitude, and altitude), denudation rate causing losses and the time duration. When samples evidenced more complex exposure histories including both exposure and burial, the measurement of two nuclides accumulated in the same mineral helps to better understand the processes involved and quantifying the timing. In this paper was measured both ¹⁰Be (half-life of $1.387 \pm 0.0012 \times 10^6$ (Chmieleff et al., 2010; Korschinek et al., 2010)) and ²⁶Al (half-life of $(7.05 \pm 0.17) \times 10^5$ (Samworth et al., 1972)).

At Revilleja de Valparaíso site, the use of these two nuclides in a set of different samples collected at the same depth within the same sediment deposit allows us to determine the time since they were emplaced, using their inherited cosmogenic content remaining from a previous exposure and assuming that they all accumulate the same amount of nuclides after deposition (because they are at the same location and same depth) (Balco and Rovey, 2008; Granger, 2006; Granger and Muzikar, 2001). This approach, the so-called burial dating is extensively explained in Granger (2014) and other papers (Husson et al., 2022; Pappu et al., 2011). Further details are provided in Appendix A. Supplementary material, 2 Terrestrial Cosmogenic Nuclide (TCN) dating section.

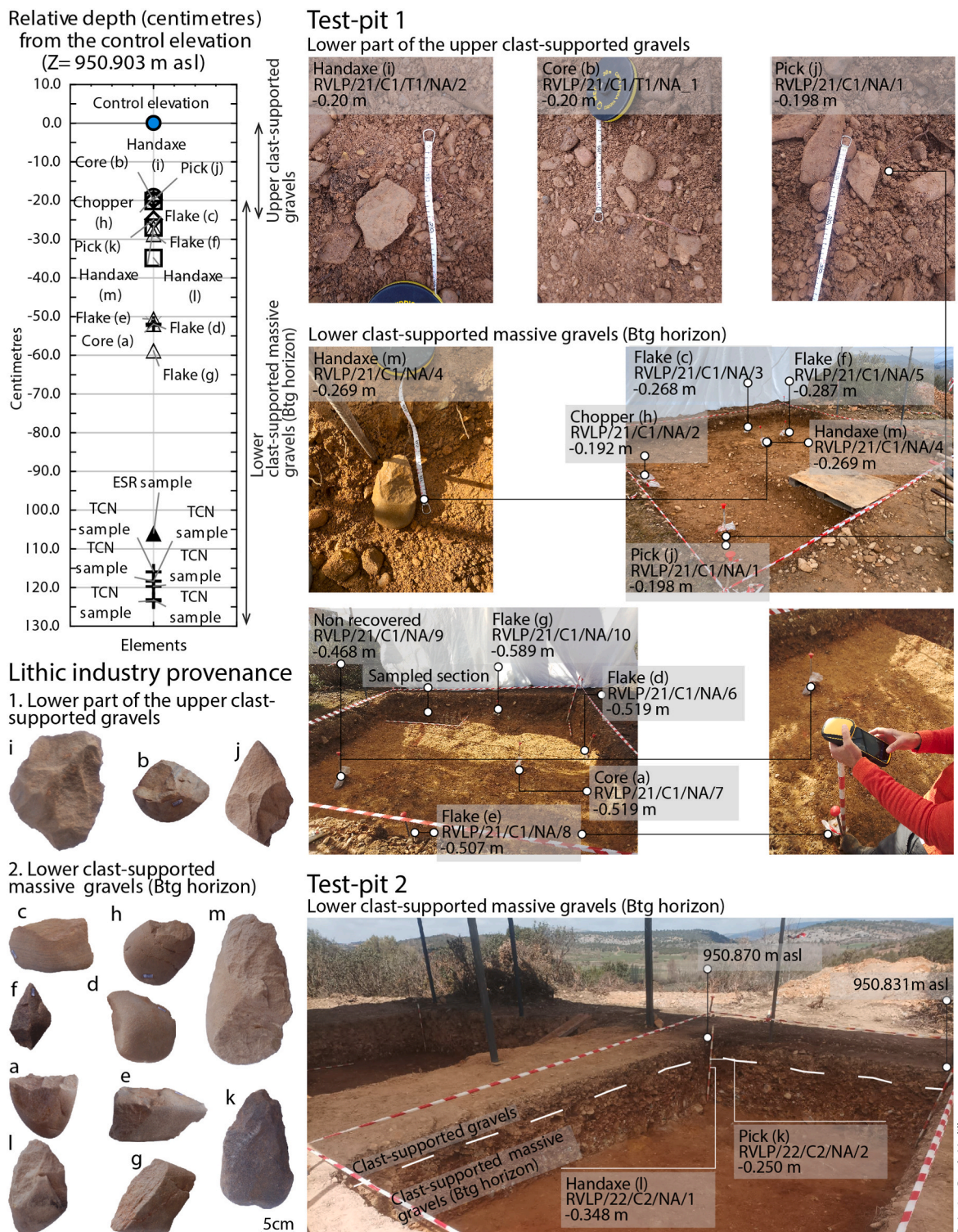


Fig. 4. Depths and sedimentary context in which the lithic artefacts were recovered from the two test-pit areas at the top of the hill. A detailed list of georeferenced items is provided in [Supplementary Table S 1](#). The alphabetic code (letter) assigned to the lithic artefacts is the same as that used in [Figs. 3 and 7](#). Figure created using Inkscape-1.4 (<https://inkscape.org/>). (F.-J. García-Vadillo).

3.2.2.2. Electro Spin Resonance (ESR) dating method. Quartz extraction from sample VP2101 was performed following the protocol described in [Appendix A](#). Supplementary material, 3.1 Methods and [Supplementary Table S 4](#). The Multiple Aliquots Additive (MAA) dose approach was applied to date quartz grains from the VP2101 sample. The study utilised 14 multiple grain aliquots, with 12 subjected to incremental irradiation (150–35,000 Gy) using a calibrated ^{137}Cs gamma source, while

one aliquot was preserved in its natural state, and another was optically bleached to evaluate the non-bleachable residual signal of the aluminium (Al) centre. Electron Spin Resonance (ESR) measurements were conducted at 92 K using an EMXmicro 6/1 Bruker X-band spectrometer at the ESR dating laboratory of the CENIEH, and the Multiple Centre approach was applied to measure Al and Titanium (Ti) centres. Equivalent dose (D_E) values were determined through Microcal Origin

8.5 using the Levenberg-Marquardt algorithm, employing specific fitting functions for each centre. The dose rate was derived from laboratory high-resolution gamma spectrometry (HRGS) analyses, with corrections for water content, grain-size attenuation, and cosmic radiation effects. As mechanical failures prevented direct *in situ* gamma dose measurements, dose rate calculations were based on the elemental composition of the sample. The final total dose rate was computed using dose rate conversion factors and attenuation corrections, assuming an internal dose of $50 \pm 30 \mu\text{Gy/a}$. ESR age estimation was performed using DRAC v1.2, incorporating uncertainty assessments based on multiple parameters. Further details are provided in [Appendix A. Supplementary material, 3 ESR dating on quartz from sample VP2101 at Revilla de Valparaíso \(Hortigüela, Spain\) section.](#)

3.2.2.3. Combined dates. Bayesian methods were employed in OxCal 4.4.4 ([Bronk Ramsey, 2016](#)) to integrate the three numerical dates and their uncertainty ranges into a representative chronological interval, thereby generating a more robust probability distribution. Following protocols for non-radiocarbon dating ([Demuro et al., 2020](#)), the dates were treated as calendar dates ("c_date") to ensure that the probabilities were directly comparable in the modelling using the "Combine" function. Further details are provided in [Appendix A. Supplementary material, 4 Site age estimation: Bayesian modelling of the obtained dates section.](#)

3.2.3. Analysis of the lithic industry

The analysis of the lithic industry was based on the concept of the operational chain ([Geneste, 1991](#)), the analytical logical system ([Carbonell et al., 1983, 1992](#)) and the concept of operational field ([Guilbaud, 1995](#)) (see [Appendix A. Supplementary material, 5 Analysis of the lithic industry for further details.](#)) The analysis considered the types of knapped rocks and possible provenance, the blanks used (cobble/pebble or flakes) and the objectives of the sequences (reduction and shaping).

The lithic artefacts were measured, classifying them according to their morphological and technological axes, classifying those larger than or equal to 100 mm as large-size format elements. For the cores, reduction strategies were defined ([Supplementary Fig. S 5](#)) through analysis of the number of flaked surfaces (faciality), arrangement of the flaking planes and reduction axes, volumetric symmetry, and the perimeter occupied by the flaking removal and the knapping angles.

In the large-format shaped tools, we analysed variables similar to those of the cores. The large cutting tools ([Kleindienst, 1962](#)) include handaxes, picks and cleavers ([Tixier, 1956](#)). Some were also classified as chopper or chopping-tool. The analysis and classification of the retouched flakes followed the scheme proposed by [Laplace \(1972\)](#). The proportion of cortex on the butt and dorsal face, facets of the butts and the direction of the dorsal removal negatives were analysed on the flakes. The operational field was also analysed ([Supplementary Fig. S 16](#)), and obtained results represent the theoretical structure formed by the relationships and interactions between the technical concepts represented in the operational chains (see [Appendix A. Supplementary material, 5.1.2 Technological analysis of lithic industry section for further details.](#))

A variety of statistical tests were employed to explore potential associations between lithic assemblages (from the upper and lower gravels) and the characteristics of the identified operational chains, including objectives, structure, and shaped tool typologies. Due to the limited sample size of the two assemblages, appropriate statistical procedures were employed to analyse 2x2 contingency tables: Fisher's exact test (two-tailed and one-tailed) and Phi-square coefficient (Φ^2). Furthermore, the statistical power of the used data was estimated to identify potential limitations in detecting associations and to assess the probability of detecting a real difference when it exists. This analysis was based on a normal approximation derived from the comparison of

proportions (Z-test), taking into account the sample size, the observed effect size, and the adopted significance level ($\alpha = 0.05$).

4. Results

4.1. Dating results

4.1.1. Terrestrial cosmogenic nuclide dating results

From the six samples and the measured ^{10}Be and ^{26}Al concentrations (see [Appendix A. Supplementary material, 2 Terrestrial Cosmogenic Nuclide \(TCN\) dating and Supplementary Table S 2](#)), the best values of paleo denudation rates (one per sample), denudation rate and time since the burial event that fit all the data were determined to have the smallest residual concentrations (i.e. the minimum distance from the modelled concentrations and the measured ones) for ^{10}Be and ^{26}Al respectively. All the outputs are presented in [Supplementary Table S 3](#). The results suggest a deposition age of $680 \pm 60 \text{ ka}$.

4.1.2. Electron spin resonance dating results

The analysis of the two paramagnetic centres (Al and Ti) in quartz grains from sample VP2101 yielded noteworthy results (see [Appendix A. Supplementary material, 3 ESR dating on quartz from sample VP2101 at Revilla de Valparaíso \(Hortigüela, Spain\) section, Supplementary Table S 5 and Table S 6, and Supplementary Fig. S 3 and Fig. S 4](#)). Typically, the aluminium centre yields slightly older ages than the Ti-Li centre (option D). This is because aluminium may retain a small residual dose and is therefore typically considered a maximum age. In this case, however, the age determined from the Ti-Li centre is slightly greater than that from the aluminium centre, although statistically, they can be considered equivalent, since they fall within the margin of error. Based on the results obtained, the age of this deposit is estimated at $680 \pm 54 \text{ ka}$ (aluminium centre; 8% error) and/or $721 \pm 51 \text{ ka}$ (Ti-Li centre, Option D; 7% error). Taking into account the errors associated with each method, and considering the overlap between the two estimates, the probable age range for this deposit is between 670 and 734 ka (mean age: $702 \pm 32 \text{ ka}$).

The sedimentary heterogeneity of the site may introduce additional uncertainty in the laboratory-derived dose rate obtained for sample VP2101 ($2191 \pm 52 \mu\text{Gy/a}$). Nevertheless, this value is comparable to environmental dose rates reported for fluvial terraces of the Arlanza River dated between 600 and 700 ka, which represent the main collector system of the Valparaíso River (2197 ± 97 to $2825 \pm 116 \mu\text{Gy/a}$) ([Moreno et al., 2016](#)). This agreement with regional datasets supports the robustness of the environmental dose rate estimate, despite the inherent methodological limitations.

4.1.3. Combined dating results

The results of the Bayesian methods and statistical tests utilised in OxCal ([Bronk Ramsey, 2016](#)) to combine the three dates (see [Appendix A. Supplementary material, 4 Site age estimation: Bayesian modelling of the obtained dates section, Supplementary Table S 3 and Table S 6 and Supplementary Fig. S 2 and Fig. S 4](#)) underscore their congruence ([Fig. 5 and Supplementary Table S 7](#)). The chi-square test (χ^2 -Test) rejects the hypothesis that they correspond to distinct events. There is a high concordance between dates (Acomb and A values), although some caution should be exercised when interpreting the results, as the individual concordance levels of the three dates are moderate ($A_n = 40.8\%$). The date $696 \pm 32 \text{ ka}$ and the intervals 664-727 ka (1s) and 633-759 ka (2s) represent an age for deposit formation at the boundary of MIS 17.

4.2. Characterization of the lithic assemblage

The lithic assemblages found in the upper ($n = 3$) and lower gravels ($n = 10$) ([Table 2](#)) were knapped on rounded rocks that were available in the vicinity, including quartzite and closely related metamorphic sedimentary rocks. In both levels, large (lengths: 91-200 mm) and heavy

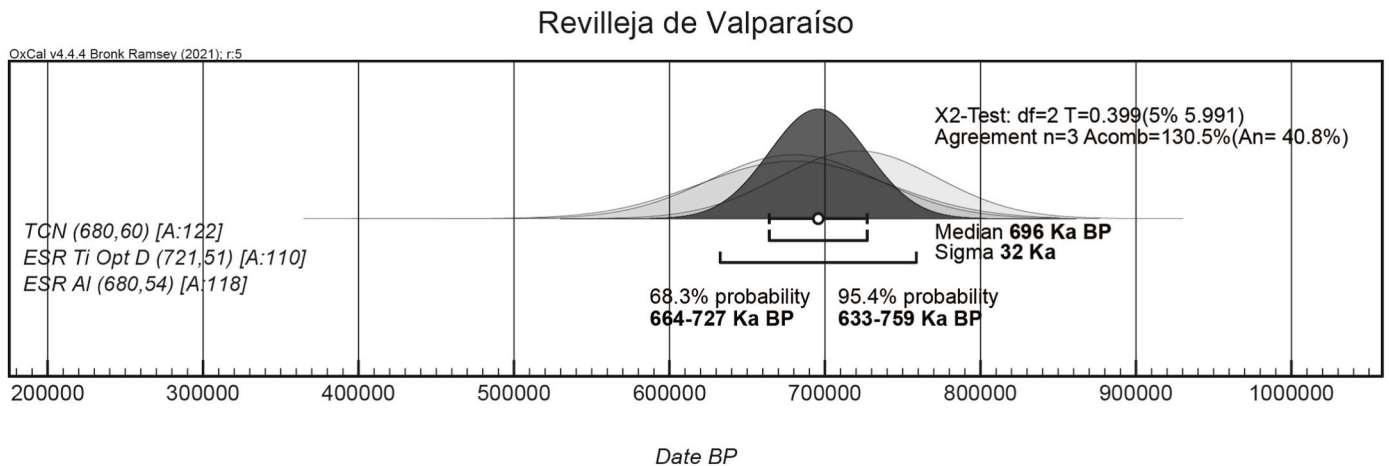


Fig. 5. Summary of the results from the Bayesian modelling analysis that was carried out using OxCal for Rivilaja de Valparaíso. The likelihood (unmodelled) and posterior (modelled) age ranges are presented. The posterior (modelled) age range is also shown as the 68.3% and 95.4% highest probability density ranges. The mean and 1s uncertainty ranges of the modelled posterior distributions are shown for comparison (assuming a normally distributed probability density function). The unmodelled and modelled age estimates have been rounded to the nearest 1000 years. All the results are given in kiloannum (ka). Results are available in [Supplementary Table S 7](#).

Table 2
Composition and blanks used in the lithic assemblages of the upper and lower gravels of Rivilaja de Valparaíso.

	Lower Gravels-Btg horizon		Upper Gravels			
	Quartzite		Quartzite			
	Total	%	Total	%	Total	%
Core	1	10%	1	33%	2	15%
On cobble	1	100%	1	100%	2	100%
Flake	5	50%			5	38%
Shaped tools	4	40%	2	67%	6	46%
Chopper/	1	25%			1	17%
Chopping tool						
On cobble	1	100%			1	100%
Handaxe	2	50%	1	50%	3	50%
On cobble	1	50%			1	33%
On flake	1	50%	1	100%	2	67%
Pick	1	25%	1	50%	2	33%
On cobble	1	100%			1	50%
On flake			1	100%	1	50%
Total	10	100%	3	100%	13	100%

objects were identified (Fig. 6), mostly classified as shaped tools (Table 2).

The representativeness of the identified operational chains related to reduction and configuration objectives varies according to stratigraphic levels (Table 2). At the Upper Gravels, shaped lithic artefacts predominate (n = 2), and no flakes were recorded. Statistical tests (Fisher's exact test, p > 0.05) indicate a statistically non-significant association, with a small effect (Phi² = 0.051) in the relationship between operational chain objectives and levels, explaining ~5% of the variance in the contingency table. However, the low estimated statistical power (power = 0.029) indicates a very limited capacity (~3%) of the analysis to detect small differences between both levels.

The relative importance of the identified shaped tools typologies also varies between the two stratigraphic levels, particularly due to the presence of a single chopper recorded in the Lower Gravels-Btg horizon (Table 2). Excluding this chopper, the potential associations represented in the percentage variations of trihedral picks and handaxes, analysed through statistical tests (Fisher's exact test, p > 0.05), indicate a statistically non-significant association, with a small effect (Phi² = 0.028) of this relationship, explaining ~3% of the total variance associated in

contingency table. However, the statistical power (power = 0.009) indicates an almost null capacity to detect differences.

Variations are observed in the blanks used to make the recorded shaped tools typologies (Table 2). Only flakes were employed on the Upper Gravels, while both flakes and cobbles were used on the Lower Gravels-Btg horizon. Statistical tests (Fisher's exact test, p > 0.05), indicate that this association is statistically non-significant, although the effect of this relationship is strong (Phi² = 0.50), explaining ~50% of the total variance in contingency table. However, the statistical power (power = 0.014) indicates an almost null capacity to detect differences. Furthermore, there are also differences in the types of blanks used to shape trihedral picks and handaxes. The statistical tests (Fisher exact test p > 0.05) indicate that statistically is a non-significant association, although the effects of the relationship are strong, especially for trihedral picks (Phi² = 1.00), which explains 100% of the total variance in the table. The strength of this relationship is also substantial for the types of blanks used to produce handaxes (Phi² = 0.250). In any case, due to the limited sample size and the extreme distribution of frequencies in the types of blanks used, it is not possible to calculate a reliable statistical power to detect differences between both two lithic assemblages.

At the technological level, the analysis of the techno-typological categories identified in the two lithic assemblages allows for the characterisation of the reduction and configuration strategies, as well as the typologies of the recorded shaped tools.

The two cores recovered from the two levels (Table 2, Fig. 7) are cobbles where the reduction process ended before they were exhausted (maximum lengths: 91-105 mm, Fig. 6). They exhibit a longitudinal unipolar unifacial reduction with a horizontal cortical striking platform and parallel scars in a confined reduction front (<50% of the perimeter). The technical lengths of the flaking surfaces limit the technical length of the flakes obtained to a small size (54-50 mm). The flakes would have cortical butts and, in most cases, cortical distal surfaces and cortical backs following the lateral and distal overpass of the flaking planes.

The shaped tools (n = 6, Table 2, Fig. 7) are the largest objects (136-200 mm, Fig. 6), and comprise three handaxes, two trihedral picks and one chopper tool recovered from the Lower Gravels-Btg horizon with a straight dihedral edge and a series of unifacial removals. The blanks utilised to make these tools are cobbles and cortical flakes (entame), which are wider than they are long (technical lengths: 100-121 mm, Fig. 6, Supplementary Table S8). In the upper gravels assemblage, two of the three recovered lithic artefacts were made on flakes (a trihedral pick and a handaxe).

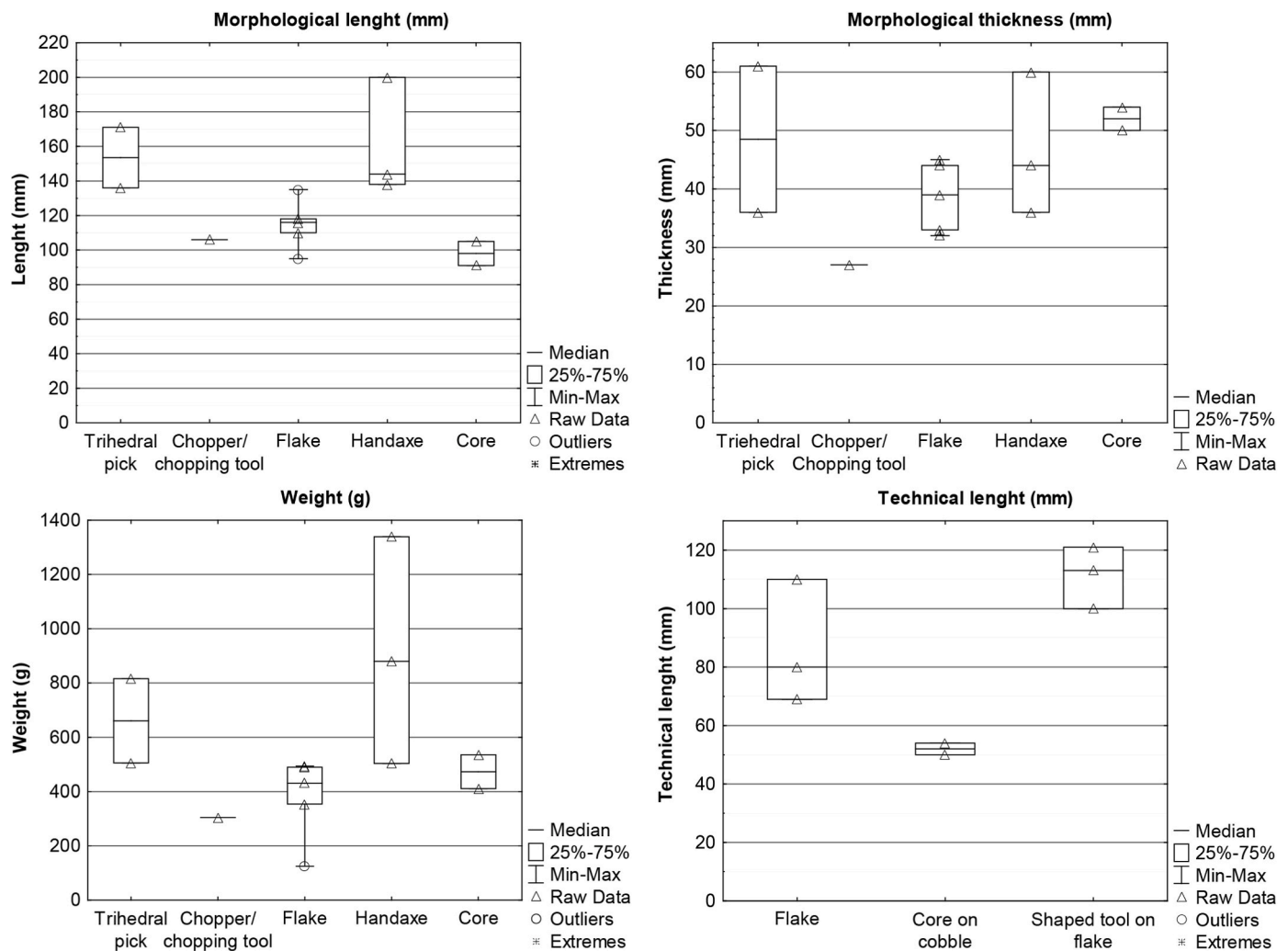


Fig. 6. Length, thickness, weight and technical length of the stratigraphic lithic assemblage.

Two of the three handaxes are shaped on flakes (Table 2, Fig. 7). These have bilateral and distal bifacial removals that span >50% of the total perimeter. The removals thin and modify the initial morphology to generate associations of lateral dihedrons with short convex distal dihedrons and a trihedron. Two of the handaxes have a single series of removals. However, one of the specimens, the only one recovered from the Upper Gravels, exhibits multiple series and a more irregular morphology, suggesting post-fracture modification and re-planning of the initial shaping of the proximal part (Figs. 7 and 8).

The two trihedral picks on cobble and flake (Table 2, Fig. 7) display unifacial and bifacial removals covering less than 50% of the perimeter and delineating lateral dihedrons with a distal trihedron where they converge. Abrupt bilateral removals cover the entire transverse surface.

All flakes ($n = 5$, Table 2, Fig. 7) except one fragment are >100 mm length (Fig. 6). All have cortical butts. One also has a cortical dorsal face. Three overpass the flaking planes of the cores and have cortical distal surfaces. The dorsal parallel negatives, the cortical butts and the arrangement of the dorsal cortical surfaces suggest they were produced by unifacial unipolar longitudinal reduction. Their technical lengths (65–110 mm) and those of the flake blanks tend to be greater than the technical axes of the flaking surfaces of the cores (Fig. 6).

Regardless of their sedimentary context, technical similarities are observed among the lithic artefacts within each identified category. There is a technical correspondence between flakes and cores; however, although the technical lengths of the flakes exceed the productive capacities of the cores, as defined by the technical lengths of the flaking

surfaces (Fig. 6), they are likely to have been obtained in the immediate vicinity of the site. The large shaped cortical flakes suggest a preferential selective pattern of transport and use of these blanks to shape LCTs (Fig. 9, Table 2, Supplementary Table S 9). The handaxes and trihedral picks display technical affinities, resulting from minimal knapping, and morphological analogies, due to the presence of distal trihedrons (Fig. 9, Table 2, Supplementary Table S 9). Notwithstanding these similarities, the few removals account for a variety of objectives. The different types of shaped tool are distinguished by: 1) the arrangement of the shaped planes, transverse in the trihedral picks and horizontal in the handaxes; 2) the extent of the shaped perimeter, greater in the handaxes than in the trihedral picks; and 3) the angles of the lateral dihedrons, obtuse in the trihedral picks and acute in the handaxes. The chopping tool has similar knapping to the cores.

5. Discussion

Revilleja de Valparaíso provides important information on: 1) the origin, extent and continuity of early European Acheulean technical traditions; 2) the occupational gaps in the Iberian Peninsula; and 3) the origin of the Iberian Acheulean singularity. The chronological and technological particularities of these contributions must be analysed in the Iberian, North-Pyrenean and circum-Mediterranean context.

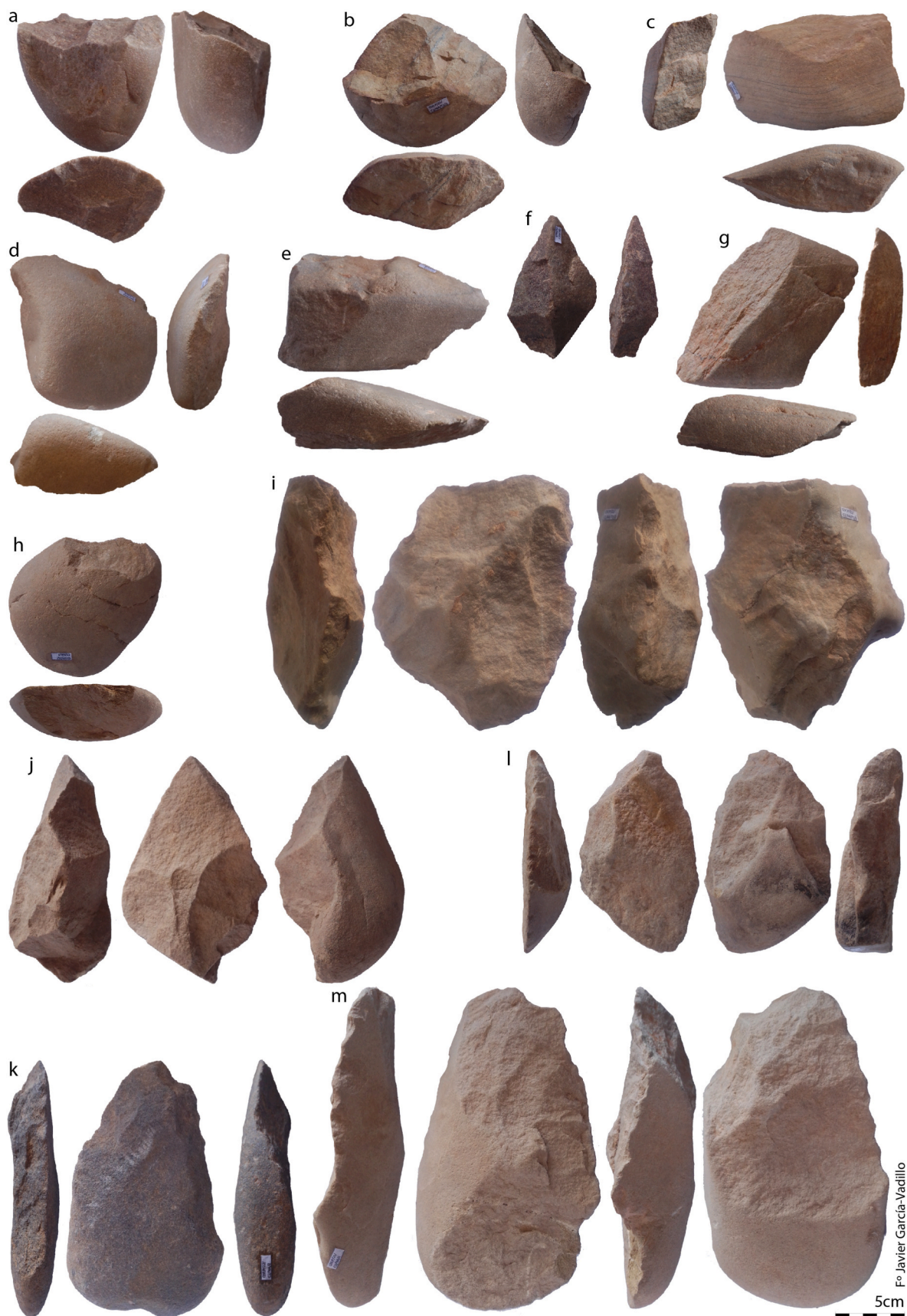


Fig. 7. Lithic industry in stratigraphic context made of quartzite from the Upper Gravels (i, b, j) and Lower Gravels-Btg horizon levels (a, c-h, k-l): cores on cobble (a-b); flakes (c-g), chopping tool on cobble (h); trihedral picks (j-k) on cobble (k) and flake (j) and handaxes (i, l-m) shaped on flake (i, l) and cobble (m). Element i is shown schematically in Fig. 8. The alphabetic code (letter) assigned to the lithic artefacts is the same as that used in Figs. 3 and 4. (F.-J. García-Vadillo).

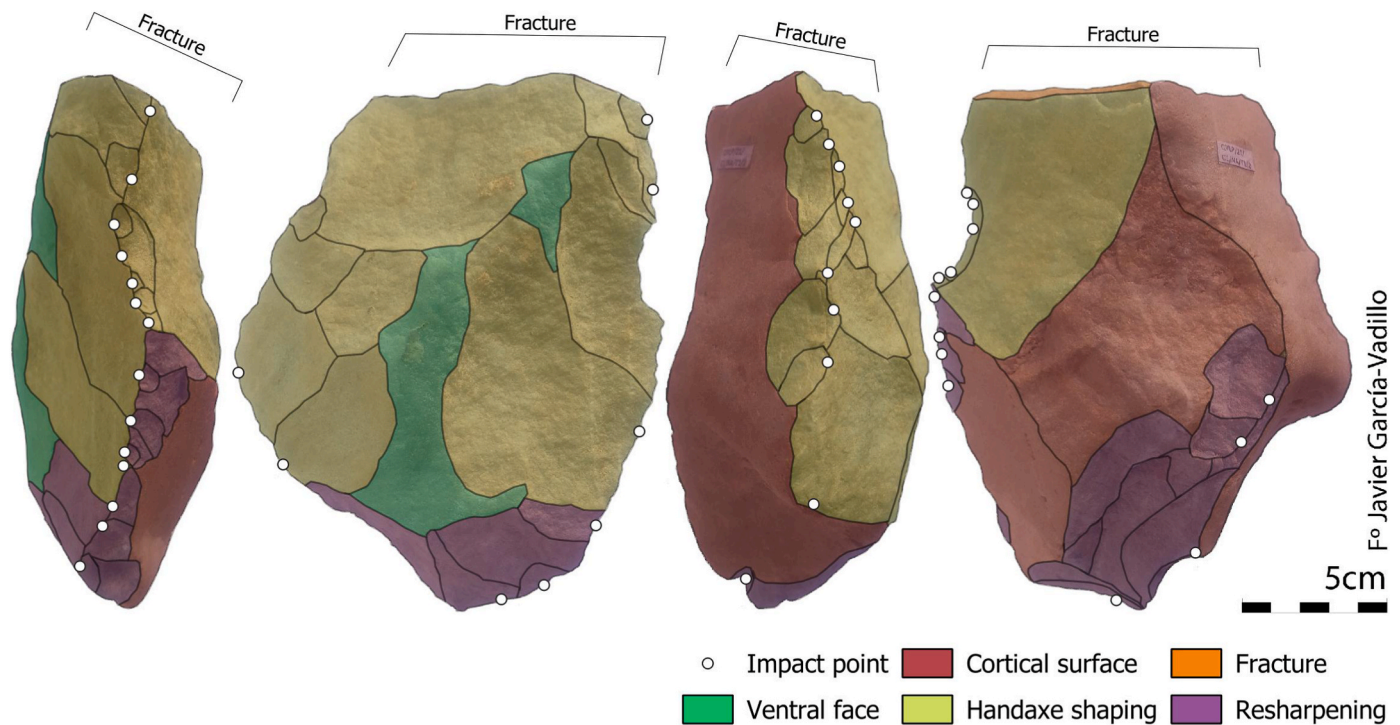


Fig. 8. Diagram of a handaxe showing distal fracture and reshaping of the proximal area. (F.-J. García-Vadillo).

5.1. The age of Revilleja de Valparaíso

In order to support the relevant information provided by Revilleja de Valparaíso, the numerical ages, the relationship between the lithic assemblage and the dating results, as well as the significance of these dates in the context of the dated terraces of Arlanzón and Arlanza river valleys must be examined.

5.1.1. Reliability of dating results

The reliability of the proposed age (696 ± 32 ka) for the massive clast-supported gravel level (Lower Gravels-Btg horizon) of Revilleja de Valparaíso is supported by the use of two independent dating methods (TCN and ESR) that yield three age estimates (see Dating results section, Fig. 5 and Supplementary Table S 7). Both methods involve sources of uncertainty inherent to their respective analytical approaches for estimating ages from quartz sedimentary particles. These age estimates are based on independent markers that measure the time elapsed since these particles were exposed to cosmic radiation (TCN) and their last exposure to sunlight (ESR). Furthermore, the multi-centre approach within the ESR method provides an additional level of internal validation for these estimates.

Given that the sedimentary particles analysed originate from the same stratigraphic level and that the three age estimates obtained using independent methods are statistically indistinguishable (even considering the differences between the results from the Ti Option D and Al centres), it can be inferred that the duration of exposure to cosmic radiation and the time elapsed since the last exposure to sunlight are consistent. Therefore, the estimated age of the deposit (696 ± 32 ka) can be regarded as robust. The analysed quartz particles appear to reflect relatively uniform sedimentary processes in terms of transport, last exposure to sunlight, and cosmic-ray exposure. Consequently, the estimated age is representative of the massive clast-supported gravels (Lower Gravels-Btg horizon), within which ten lithic artefacts were found imbricated among the clasts of the deposit.

5.1.2. Relationships between the sedimentary sequence, the lithic industry, and the dated sediment samples

The representativeness of the dated samples as indicators of the burial age of the Revilleja de Valparaíso lithic industry is based on the relationship between four parameters of the lithic materials from the two gravel levels: 1) their location; 2) the sedimentary processes that preserved them; 3) their similar surface alterations; and 4) the technological analogies that were identified.

The minor variations observed in the sedimentary processes that formed the two gravel levels, which preserve the lithic assemblages, indicate a stratigraphic differentiation, reflected in the massive character of the lower gravels level and in the differences in the pedogenic processes affecting both levels. The sinuous contact between both levels suggests that the upper eroded the lower one after the Btg horizon was formed. Regarding this sinuous contact, the sedimentary context of lithic artefacts at the base of the upper gravels indicates that this contact is located at a medium depth of approximately 20 to 26 cm, and maximum depth of 40 cm (see Figs. 3 and 4).

From 20 to 26 cm depth, the sedimentary changes observed during the excavation, including the loss of organic matter from the gravels and the appearance of reddish and greenish tones in the Btg horizon matrix, suggest that this interval delineates the boundary between upper and lower gravels and their respective lithic artefacts (see Figs. 3 and 4). The 6 cm range between 20 and 26 cm depth matches: 1) the thickness of the upper gravels and the sinuous morphology of their lower contact; and 2) the maximum variation of 7 cm in the elevations of six corners of the test-pit areas relative to the control elevation level (see Fig. 3 and Supplementary Table S 1). Although two corners in the southern area of Test-Pit 2 are 15–20 cm below the control elevation, the two lithic artefacts recovered in the northern area originate from the lower gravels level. Consequently, there are three lithic artefacts recovered from the Upper Gravels and ten from the Lower Gravels-Btg horizon.

The total range of 40 cm separating all the lithic artefacts recovered from the lower level occurs in a deposit with few finds and a sedimentary context of massive clast-supported gravels where large, heavy and thick objects were preserved (Fig. 6). Considering these sedimentary characteristics and the sizes of the lithic artefacts, the 10 cm intervals and the

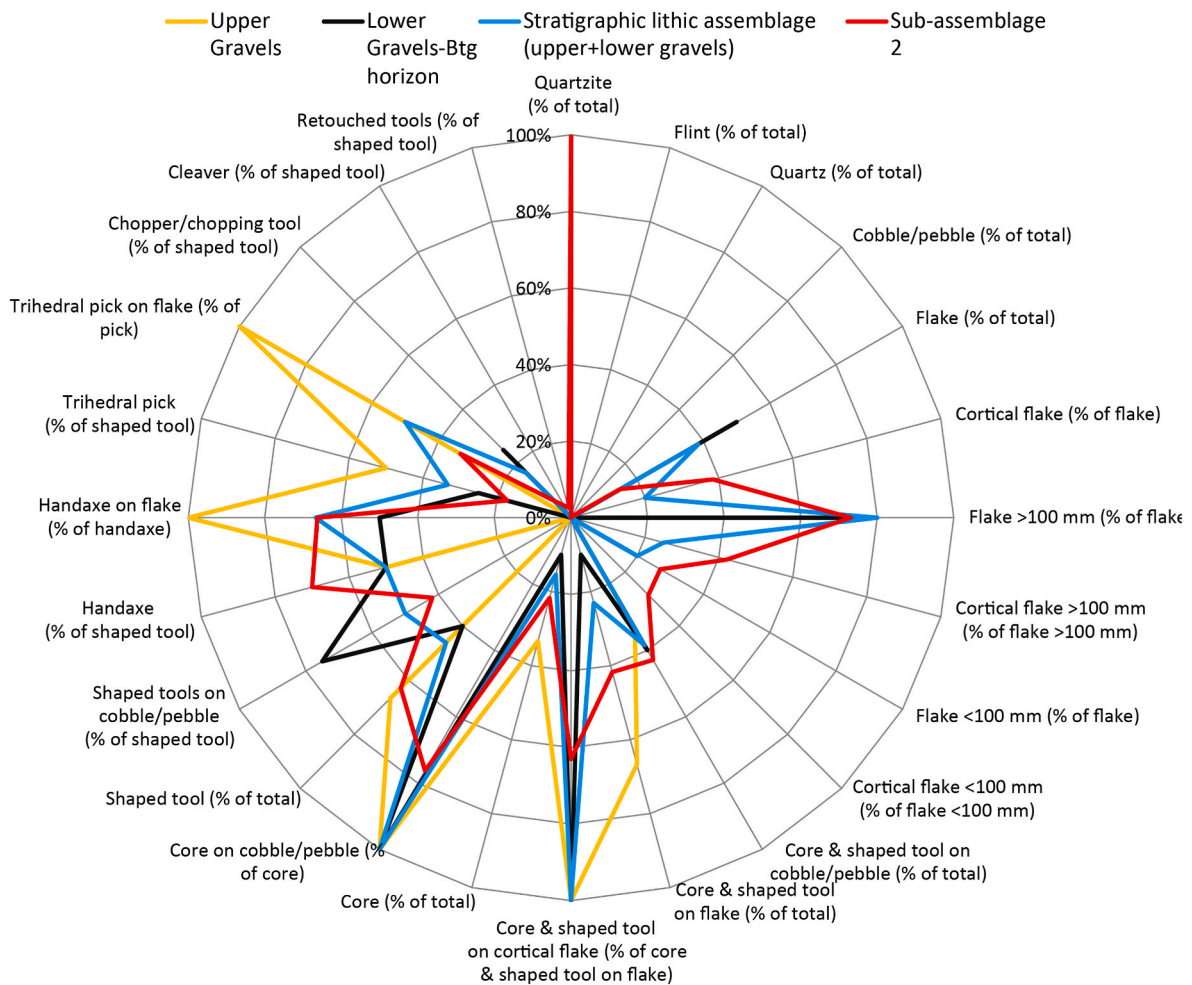


Fig. 9. Main features of the stratigraphic lithic assemblages and sub-assemblage 2. The comparative data can be found in the [Supplementary Table S 9](#).

16 cm vertical distance represented by the depth ranges in which these objects were found constitute minimal differences. Although these differences are minimal, observations of sedimentary context during excavation at 20 to 26 cm depth indicates that three lithic artefacts come from the Upper Gravels, whereas the remaining ten derive from the Lower Gravels-Btg horizon. Therefore, although the sediment samples used for dating were collected approximately 47 cm below the deepest occurrence of lithic artefact, this vertical distance is minimal and also reduces the risk of contamination by sedimentary particles that could otherwise affect sample quality. In any case, the Lower Gravels-Btg horizon lithic assemblage and the collected sediment samples originate from the same level.

The lithic artefacts of the two gravel levels have similar surface alterations and technical characteristics, suggesting that they belong to the same lithic assemblage (see Fig. 7 and Characterization of the lithic assemblage section). Although the statistical analyses are not strong enough to detect significant differences between the two lithic assemblages, the technical analogies identified in the reduction strategies, shaping objectives, and knapping sequences (Fig. 9.), suggest that these are a homogeneous lithic assemblage. Moreover, the relationship between these technological analogies of both lithic assemblages together with the stratigraphy, in addition to the depths distribution of lithic objects, suggests that the later erosive event, represented by the upper gravels, incorporated part of the lithic artefacts from the lower level. These lithic artefacts had been previously deposited in the lower gravels level where the Btg horizon was formed. Subsequently, an A horizon developed on the Upper Gravels, with bioturbation introducing organic matter into its matrix.

The main sedimentary differences between the contexts of both lithic assemblages represent only a minor variation, identified in the massive character of the gravels. However, the differences in the pedogenic processes affecting both levels and their stratigraphic relationship indicate diachrony. This diachrony introduces a factor of temporal uncertainty, further reinforced by the development of a Btg horizon within the lower gravels level, indicating a well-developed soil profile. Therefore, this uncertainty affects only the three lithic artefacts recovered in the undated Upper Gravels level.

Taking into account the relationships and uncertainties regarding the lithic artefacts from both alluvial levels, only the ten lithic artefacts recorded in the sampled Lower Gravels-Btg horizon provide a basis for concluding that the proposed date of this deposit represents the age of this lithic assemblage. Although it is possible that the lithic artefacts from both gravel levels derive from a single assemblage, the sedimentary unconformity between the two levels prevents these dates from representing the age of only three lithic artefacts recorded in the Upper Gravels.

5.1.3. The age of Revilleja de Valparaíso in the context of the Duero River basin

The estimated age of the Lower Gravels deposit (696 ± 32 ka, Fig. 5) represents an anomaly in the Arlanza and Duero basins (Table 1). Taking into account the dated and well-preserved tread terraces of the Arlanza and Arlanzón rivers (Table 1), the relative altitude of the site (+29–30 m) places the archaeological findings *a priori* at >230 ka (T + 12–17 m for the Arlanza) and around 348 ka (T + 33–36 m for the Arlanzón) (Arnold et al., 2013; Benito-Calvo and Pérez-González, 2015; Benito

Calvo, 2004; Moreno et al., 2016). This anomaly in the Arlanza valley suggests that the sedimentary sequence corresponds to the base or strath of a degraded terrace rather than the terrace treads measured in the Middle Arlanza and Arlanzón Valley, or that there are substantial chronological and altitudinal discrepancies between the terrace systems developed by the Arlanza, upstream and downstream of the Las Mambas canyon (Fig. 2c).

The thinness of the sedimentary sequence at the site, the presence of Cretaceous bedrock outcrops at several points, and the location of the deposit on a hummocky hill without a well-preserved terrace tread or flat top (Fig. 3) allow us to deduce that the alluvial deposit of the Lower Gravels-Btg horizon corresponds to the base or strath of a degraded terrace. The dates obtained by independent methods provide robust grounds for concluding that this alluvial deposit of the site can be dated to around 700 ka, the same as the terraces T + 64-67 m of the middle Arlanza or T + 50-54 m of the Arlanzón (Table 1) (Arnold et al., 2013; Benito-Calvo and Pérez-González, 2015; Benito Calvo, 2004; Demuro et al., 2024; Moreno et al., 2016).

5.2. Originality of the lithic assemblage

The lithic assemblages of Revilla de Valparaíso show evidence of the impact of fluvial agents on smaller artefacts and erosive processes that dismantled the deposits, so they are now only present at the top of the hill (Figs. 3, 6, and 7). In the preserved alluvial stratigraphic sequence, the two lithic assemblages display minimal differences in the objectives and structure of the operational chains, as well as in the types of blanks employed to shape handaxes and trihedral picks. These differences are magnified by the small number of artefacts recovered. This limited sample size severely limits the statistical power of the Fisher's exact test to detect real differences. Despite this, the surface alterations and technical similarities observed in the lithic artefacts from both assemblages suggest that the fluvial agents involved in the formation of the Upper Gravels level eroded the lower level, incorporating part of its lithic assemblage.

Notwithstanding these vicissitudes, the lithic assemblages are homogeneous. Although the small size of the preserved lithic assemblages precludes robust statistical analysis, the characteristics of the recovered lithic artefacts are nevertheless significant and are shared by both levels. The ten lithic artefacts recorded in the Lower Gravels-Btg horizon are characterised by the following: 1) a versatile technical use of quartzite and similar local lithic materials; 2) fragmented operational chains; 3) longitudinal reduction strategies that constrain the size of the flakes; 4) a frequent use of cobbles in the reduction and flakes in the shaping of LCTs; and 5) LCTs frequently featuring distal trihedrons (Table 2, Fig. 9, Supplementary Table S 9). These features are likewise present in the limited lithic assemblage from the Upper Gravels level.

Even excluding the lithic assemblage from the Upper Gravels, the technical activities, flake corticality and technical lengths of cores and flakes from the Lower Gravels-Btg horizon suggest that three allochthonous technical processes occurred: 1) cortex removal of cores; 2) the production of large flakes; and 3) the initial shaping activity. It is probable that the processes involved in forming the deposit dispersed the small-sized flakes derived from the initial reduction and shaping activities, but not the larger objects. The scarcity of preserved artefacts impedes a definitive interpretation of allochthonous technical processes, although the large flakes utilised in the shaping suggest possible fragmentation of the operational chains and planned transport strategies. The sparse shaping of the LCTs points to an accumulation of preforms at this point.

The characterisation of the lithic industry from the Lower Gravels-Btg horizon and the Upper Gravels can be improved by an analysis of sub-assemblage 2 (see Appendix A. Supplementary material, 5.2.3 Sub-assemblage 2 lithic industry and Table S 8). Its dispersion around the hill (Fig. 3) and the similarity of its alterations (see Supplementary Fig. S 6, Fig. S 7, Fig. S 8, Fig. S 9, Fig. S 10, Fig. S 11, Fig. S 12, Fig. S 13, and

Fig. S 14) and technological characteristics (Fig. 9, Supplementary Table S 8 and Table S 9, and Supplementary Fig. S 15) suggest that it corresponds to the same deposit. The technological characteristics it shares with the stratigraphic assemblages, differentiating it from other sub-assemblages, point to a non-random relationship reinforced by the use of cortical flake-blanks and the shaping of handaxes from flakes (Fig. 9, Supplementary Table S 8 and Table S 9 and Supplementary Fig. S 17 and Fig. S 18). Sub-assemblage 2 incorporates additional reduction strategies and shaped tool types that complement the structure of the operational field (*champ opératoire*) without altering it. The operational field (Guilbaud, 1995, 1996) displays the theoretical relationships established on the basis of the technical concepts represented in the operational chains of the stratigraphic assemblage (Supplementary Fig. S 16). In sub-assemblage 2, longitudinal reductions predominate and hierarchise the relationships between reduction strategies. Centripetal reductions, in this context, represent both independent concepts and derivations that emerged during the knapping process in sequences that start from a longitudinal reduction. Regarding the shaped tools, the cleavers and points increase the typological diversification of Revilla de Valparaíso.

5.3. Chronological and cultural context of Revilla de Valparaíso

Three traits link the lithic assemblage from the Lower Gravels-Btg horizon, as well as the lithic artefacts from the Upper Gravels, at Revilla de Valparaíso to the LFA traditions (Sharon, 2010): 1) the large flakes; 2) the tendency to use flakes to make handaxes; and 3) the types of LCTs. As observed in the LFA tradition, the LCTs types display a distinctive form of morphological specialisation, characterised by the association of distal pointed morphologies with trihedral picks, distal dihedrals with cleavers, and handaxes with distal trihedrons and, to a lesser extent, with dihedrons.

5.3.1. The first European Acheulean

The affinities of the lithic assemblage from the Lower Gravels-Btg horizon of Revilla de Valparaíso with the LFA contrast with the European Acheulean prior to MIS 19. Barranc de la Boella represents an Acheulean without handaxes, with abundant trihedrons and extensive use of cobbles to produce large shaped tools (Lombao et al., 2024; Mosquera et al., 2015; Ollé et al., 2023). For many researchers, the technical peculiarities of La Boella do not fully correspond to other, more classic Acheulean lithic assemblages with standardised LCTs typologies, including handaxes and cleavers, and may reflect: 1) local populations attempting bifacial manufacture under more diversified climatic conditions, 2) a local evolution from the European Mode 1, or 3) an interaction between technical behaviors characteristic of an evolved Mode 1 and others linked to African bifacial technology (Carpentieri et al., 2023; Martínez and García Garriga, 2016; Moncel et al., 2022; Mosquera et al., 2015). Researchers consider Barranc de la Boella as part of dispersal events linked to the 'Ubeidiya technological traditions (Lombao et al., 2024; Mosquera et al., 2015; Ollé et al., 2023). To date, no further evidence of this Acheulean has been identified. In relation to this earlier Acheulean event, Revilla de Valparaíso represents a new, later Acheulean episode that is both temporally and culturally distinct and aligns more closely with European Acheulean assemblages dated to MIS 16.

5.3.2. The first Acheulean in the northern Pyrenees region

The lithic assemblage from the Lower Gravels-Btg horizon of Revilla de Valparaíso is concurrent with the North-Pyrenean Acheulean traditions that emerged between 700 and 600 ka (MIS 17-MIS 16). At the sites of Moulin-Quignon (Antoine et al., 2019), La Noira-stratum a (Moncel et al., 2013), Notarchirico (Moncel et al., 2020b; Piperno et al., 1998), and possibly Bois-de-Riquet US4 (Bourguignon et al., 2016), shared technical traditions appeared that continued after MIS 12. With the exception of the lithic assemblage of Bois-de-Riquet US4, which lacks LCTs and exhibits other distinctive features (Table 3), the main characteristics of these lithic assemblages are: 1) predominant use of

Table 3

Main features of the sites with industries representative of the ancient Acheulean traditions of Western Europe. The number of objects from Moulin-Quignon corresponds to the 2016–2019 digs (Moncel et al., 2022); in Notarchirico, to the data from the Piperno and Moncel digs (data recovered from Muttillio et al. (2021)) and in Barranc de La Boella to the industries recovered in unit 2 in the localities of El Forn, La Mina and Pit 1 (Ollé et al., 2023). In Revilleja de Valparaíso, the entries marked with an asterisk (*) correspond to the features of sub-assemblage 2 (see Appendix A. Supplementary material, 5.2.3 Sub-assemblage 2 lithic industry for more information). (Other abbreviations: Bip. perc. = Bipolar percussion on anvil).

	Barranc de La Boella-Unit 2	Bois-de-Riquet-US4	Moulin-Quignon	Notarchirico	La Noira	Revilleja de Valparaíso
MIS	MIS 22	MIS 19-MIS 17	MIS 16	MIS 17/16	MIS 16	MIS 17
Number of lithics	966	301	278	~3600	918	13 175*
Local lithic raw materials	Yes	Yes	Yes	Yes	Yes	Yes
Lithic raw materials	Flint/Chert Schist Granite Sandstone Quartz Quartzite Limestone Lydite Porphyry	Basalt Quartz Aplite Quartzite Flint/Chert Gneiss	Flint/Chert	Flint/Chert Limestone Quartzite Quartz	Flint/Chert Limestone Quartz Other silicifications Quincite Granite	Quartzite
Differential use of raw materials	Yes	Yes	No	Yes	Yes	No
Flaking Techniques	Freehand Bip. perc.	Freehand Bip. perc. Throwing perc.	Freehand	Freehand Bip. perc.	Freehand	Freehand
Reduction strategies	Longitudinal Orthogonal Centripetal Multipolar multifacial	Longitudinal Opposite Orthogonal	Longitudinal Centripetal Orthogonal	Longitudinal Orthogonal Multifacial Centripetal	Longitudinal Centripetal Orthogonal	Longitudinal Centripetal*
Differential use of blanks	No	No	No	No	No	Yes
LCTs	Pick		Handaxe	Handaxe	Handaxe	Handaxe Trihedral pick Cleaver*
Preferential blanks of LCTs	Cobble		Undetermined (Cobble?)	Cobble	Cobble (Flake = 5)	Flake
Preferential blanks of handaxes			Undetermined (Cobble?)	Cobble (Flake = 4 or 5)	Cobble (Flake = 0)	Flake (Flake = 2)
Other large tools	Chopper/ chopping tools Knives Cleaver-like tool Retouched large flake	Biface Chopper/ chopping tools Retouched large flake	Rabot Thick scraper crudely-made bifacial pieces (Chopper/chopping tools)	Chopper/ chopping tools Cleaver-like tool	Chopper/chopping tools Cleaver-like tool Rabot Notch End-scraper Scraper Shaped tool Triface Uniface	Chopper/ chopping tools
Shaped large flakes (number)	5	>15	Unpublished	6 (4 or 5 bifaces)	38 (large retouched fakes = 33)	3
Small shaped and retouched tools	Denticulate Scraper Notch Bec Retouched flakes Chopper/ chopping tools	Notches Denticulates Retouched pieces	Convergent scrapers Scrapers End scrapers Retouched pieces	Notches Denticulates Points (Borer) Scraper	Side-scraper Denticulate Notch Composite tools Bec	Point*
Blanks of small shaped and retouched tools	Flakes Pebbles	Flakes	Flakes	Flakes Pebbles/cobbles	Flakes	Flakes*

local raw materials and no evidence of debitage from stones brought to sites from distant outcrops, 2) occasional complex large and small flake production (core technologies), 3) low ratio of bifaces, when present, and association of elaborate bifaces and partial bifacial tools, 4) diversity of shaping modes and forms for bifaces and bifacial tools (non-standardisation) with some evidence of soft percussion, 5) lack of cleavers on flakes in north-western areas, and 6) rare use of large flakes for making the heavy-duty component or for debitage (little evidence of fragmentation of the reduction processes) (Moncel and Ashton, 2018; Moncel et al., 2020a).

The North-Pyrenean lithic industries of MIS 16 exhibit similarly diverse types of LCTs (Moncel and Ashton, 2018; Moncel et al., 2020a).

Distal trihedrons are rare, and cleavers were replaced by other shaped tools with analogous morphologies, characterised, among other trends, by a loss of diversity in technical traditions (Carbonell, 1986; Carbonell et al., 1992; García-Vadillo et al., 2022, 2023; Santagata et al., 2020). Examples of the fracturing of the distal zones of the handaxes to generate dihedrons can be found in some sites, such as Moulin-Quignon, Brandon Field (MIS 15) and Boxgrove (Moncel et al., 2016, 2022; Roberts and Parfitt, 1999; Tuffreau et al., 2008). In addition, the presence of a small number of trihedrons has been identified as a link to southern influences, for example, at the Revelles site (MIS 8) (Lamotte et al., 2019). Furthermore, the utilisation of large flakes for the shaping of LCTs was infrequent. At Revilleja de Valparaíso, the three large flakes employed

for shaping two handaxes and a trihedral pick represent a higher frequency of use in comparison with other sites in MIS 16 and Barranc de la Boella (Table 3). Even considering only the lithic assemblage from the Lower Gravels-Btg horizon, the manufacture of LCTs on large flakes appears to have been a sufficiently widespread technical option to be preserved in this deposit. At La Noira, five large flakes were utilised to shape heavy-duty tools, and the handaxes were made using cobbles (Moncel et al., 2020a). Additionally, sub-assemblage 2 at Revilla de Valparaíso suggests the possibility that cleavers and centripetal reductions with symmetrical and asymmetrical volumetric structures may also have been present (Supplementary Fig. S 11).

The types of LCTs shared by Revilla de Valparaíso, the North-Pyrenean sites and Barranc de la Boella (Table 3) display uniformity (Barsky et al., 2021; Carbonell et al., 2016, 2018; García-Vadillo et al., 2023). This uniformity is fundamental for identifying these morphologies and establishing that these populations participated in a shared Acheulean technical tradition (Key, 2023; Mishra et al., 2010; Moncel et al., 2020a; Rineau et al., 2023). However, the observed differences in the diversification of LCTs typologies and the structure of the operational chains used to reach similar objectives suggest that the technological affinities of the Revilla de Valparaíso site are distinct. Despite the scarcity of preserved material, the frequent use of flakes to make LCTs is noteworthy. The absence of LFA-related industries in the North-Pyrenean territories during MIS 16 suggests that the Pyrenees may have delineated the extent of these two traditions prior to MIS 13. It is only in later phases that the influence of LFA traditions is seen to have reached neighbouring territories at more northern latitudes (Mourre and Colonge, 2016), for example at the Menez-Dregan I site (Ravon et al., 2022).

5.3.3. The North African Large Flake Acheulean

In the circum-Mediterranean Acheulean context, the dates from the North African sites of Thomas Quarry Unit-L and Oued Boucherit (1.67–1.3 Ma) (Duval et al., 2021; Gallotti et al., 2021) indicate that the chronology of Revilla de Valparaíso represents a later Acheulean. The chronological and technological affinities of Revilla de Valparaíso suggest that the LFA technical traditions present in North Africa between 0.9 and 0.8 Myr (Fig. 1) arrived in Iberia via the Strait of Gibraltar.

These LFA groups produced industries similar to those of Tighennif (ex Ternifine) (Geraads et al., 1986) and Errayah (Derradji, 2006) (0.8 Myr), also characterised by the frequent use of flakes, and, as at Revilla, mainly cortical flakes (*entame*) to shape handaxes and Type 0 cleavers (Sharon, 2011). As is suggested by the Casablanca LFA sequence (Gallotti et al., 2023; Geraads et al., 2004; Mohib et al., 2019; Raynal and Mohib, 2016; Raynal et al., 2002, 2005; Rhodes et al., 2006), these industries also extended into western North Africa during the 0.7–0.45 Myr period (MIS 17–MIS 12). In this sequence, characterised by cleavers and the frequent use of cobbles to produce handaxes (Mohib et al., 2019; Raynal et al., 2004, 2023; Raynal and Mohib, 2016), Bears Cave (Grotte des Ours, 0.4 Myr) represents a cultural shift (Mohib et al., 2019; Raynal et al., 2004) with respect to the previous sites at Thomas Quarry and at Rhinoceros Cave. In Bears Cave, as in Tighennif and Errayah, these groups predominantly used large flakes to make handaxes. The extension of the characteristics of the Tighennif and Errayah lithic industries to other areas explains, therefore, the affinity of Revilla de Valparaíso with the LFA traditions.

Revilla de Valparaíso and the North-Pyrenean and circum-Mediterranean Acheulean sites dated between 0.8 and 0.6 Myr suggest population growth following the demographic crisis identified between 0.9 and 0.8 Myr (MIS 22–MIS 20). This crisis, a 'bottleneck' identified through statistical modelling, genetics and the sparse archaeological record (Hu et al., 2023; Muttoni and Kent, 2024), may be relevant to the genesis of the cultural divergence and dichotomous geographical origin of the Acheulean that reached Western Europe in MIS 17–MIS 16. In MIS 19–MIS 18, which coincides with the most recent plausible age of the Acheulean episode at La Boella, these populations must have achieved

the robustness needed to support subsequent events. In the Mediterranean region, during MIS 17–MIS 16, these populations made possible: 1) the confluence around the Pyrenees of heterogeneous Acheulean traditions; 2) the overlap between the Revilla ages and the western dispersal of North African LFA features of Tighennif and Errayah towards Casablanca; and 3) the continuity of LFA traditions in the Levant at Acheulean sites such as Gesher Benot Ya'aqov and North of Bridge (Goren-Inbar et al., 2018; Sharon et al., 2010).

The Lower Gravels-Btg horizon of Revilla de Valparaíso provides valuable chronological and technological data to discuss and develop current concepts regarding the cultural dispersions that were the basis of European regional Acheulean technological traditions after MIS 19 (Moncel and Ashton, 2018; Sharon and Barsky, 2016; Tuffreau et al., 2008). Revilla repositions LFA among the ancient Acheulean traditions of Western Europe. Furthermore, it reformulates the model of migratory waves to these territories, placing the origin of the singularity and North African affinities of the Iberian Acheulean in MIS 17, prior to the marine regression of MIS 16 (Alimen, 1975; Freeman, 1975; García-Vadillo et al., 2022; García-Vadillo et al., 2023; Giles Pacheco and Santiago Pérez, 1987; Méndez-Quintas et al., 2020; O'Regan, 2008; Santonja and Pérez-González, 2001; Santonja and Villa, 2006; Sharon, 2011; Sharon and Barsky, 2016; Souville, 1983). It is probable that, in later regressions, other North African populations nurtured the occupational and cultural continuity of the Acheulean of the Iberian Peninsula in the Middle Pleistocene (Key, 2023, 2024; Mosquera et al., 2013; Ollé et al., 2016). In any case, Revilla suggests that the Strait of Gibraltar is not a secondary or late pathway for the LFA traditions that characterise the Iberian Acheulean.

5.3.4. The Acheulean of the Iberian Peninsula

In the Iberian Peninsula, the new Acheulean episode of Revilla is ~100 ka older than the Gran Dolina-TD8 occupations (Mosquera et al., 2024), although these industries have not yet been attributed to a technical mode (Fig. 10). The data suggest that this episode is ~200 ka older than the Acheulean of Galería-GIIa, or even more ancient, if we consider other more recent dates for this deposit (Fig. 10). Although the chronologies of these sites point to the possibility of occupational continuity in Iberia from 600 ka onwards (MIS 15c), MIS 16 (676–621 ka) and MIS 14 (563–533 ka) represent a fundamental information gap in our understanding of the success of the Revilla de Valparaíso Acheulean episode in terms of occupational and cultural continuity.

The Iberian sites of MIS 13–MIS 12 (533–424 ka), Aroeira-x/bc levels, Sima de los Huesos, Solana del Zamborino and Galería-GIIa (if the older MIS 13 dates of this unit are considered) (Arsuaga et al., 1997; Botella et al., 1976a, 1976b; Carbonell and Mosquera, 2006; Daura et al., 2017; García-Medrano et al., 2014), record Acheulean industries in diverse occupational contexts (more details and updated references on these sites are provided in Table 4). These lithic assemblages, either through the frequent use of flakes to produce handaxes, or through cleavers, or both, represent affinities with LFA and possibly other evolved traditions in cases such as Aroeira-x/bc levels and Solana del Zamborino (Daura et al., 2018; Jiménez-Arenas et al., 2011).

At these Iberian sites of MIS 13–MIS 12, there are technical particularities that coincide with the presence of cleavers. In Galería-GIIa there are cleavers and handaxes primarily made from cobbles (García-Medrano et al., 2015). In contrast, the absence of cleavers in the Aroeira sequence (Daura et al., 2018; Marks et al., 2002) suggests an emergence of technological traditions around 412 ka ago that exhibit a loss of diversity (García-Vadillo et al., 2022, 2023). At Aroeira-level Xb/c, the frequent use of flakes to produce handaxes (Daura et al., 2018) suggests that the absence of cleavers is not due to the unavailability of lithic raw materials. Revilla could indicate a similar situation, but sub-assemblage 2 suggests that cleavers were also present (see Appendix A. Supplementary material, 5.2.3 Sub-assemblage 2 lithic industry and Table S 9).

The features of the lithic assemblage from the Lower Gravels-Btg

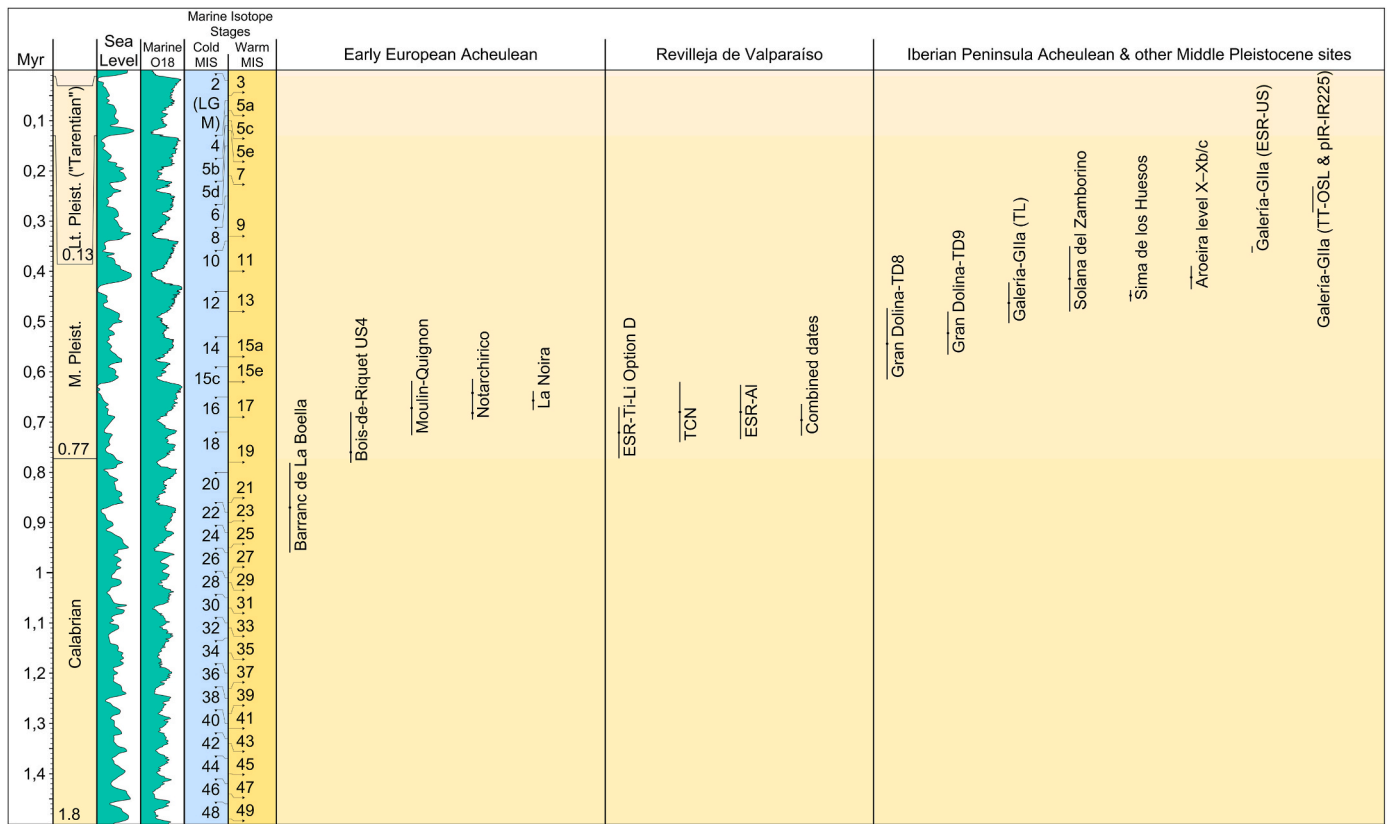


Fig. 10. Dates of Revilleja de Valparaíso in the context of ancient Acheulean and Middle Pleistocene sites known to date in Western Europe and the Iberian Peninsula: La Noira-stratum a (Duval et al., 2020); Notarchiro (average dating of the lower and upper part of the sequence) (Moncel et al., 2020; Pereira et al., 2015; Piperno et al., 1998); Barranc de La Boella (Vallverdú et al., 2014); Moulin-Quignon (Antoine et al., 2019); Bois-de-Riquet-US4 (Bourguignon et al., 2016); Gran Dolina-TD9 (the interval is defined by the maximum central measure between the ESR-AI dates (Moreno et al., 2015) and the minimum central measure between the TL & IRSL dates (Berger et al., 2008)); Gran Dolina-TD8 (the interval is determined by the maximum central measurement between the ESR/US dates (Falgüeres et al., 1999) and the minimum central measurement between the ESR-AI dates (Moreno et al., 2015)); Solana del Zamborino (Álvarez-Posada et al., 2017); Sima de los Huesos (Demuro et al., 2019); Galería-GIIa (Berger et al., 2008) and Aroeira-level X-Xb/c (Daura et al., 2017). The ages of Galería-GIIa correspond to the ranges represented by the central measurements of the dates obtained by the TL (Berger et al., 2008); ESR-US (Falgüeres et al., 2013) and TT-OSL & pIR-IR225 dating methods (Demuro et al., 2014). Figure produced with TSCreator Pro (<https://engineering.purdue.edu/Stratigraphy/tcreator>). (F.-J. García-Vadillo).

horizon of Revilleja de Valparaíso are common in post-MIS 12 and other non-dated Iberian Acheulean sites (more details and updated references on these sites are provided in Table 4) (García-Vadillo et al., 2023; Méndez-Quintas et al., 2020; Santonja and Pérez-González, 2001). In all the Atlantic fluvial basins there was a provisioning of local lithic resources, primarily quartzite and related metamorphic materials (Santonja and Pérez-González, 1984, 2001; Santonja and Villa, 2006), and less frequently other local lithic raw materials such as quartz and flint (García-Vadillo et al., 2022, 2023; Rubio-Jara et al., 2016). Other shared characteristics can also be identified, including the specialised use of blanks (cobbles in reduction and flakes in shaping), handaxes frequently shaped on flakes, and the typological diversification of LCTs, with distal trihedrons and cleavers (Table 4) (García-Vadillo et al., 2023; López-Recio et al., 2018b; Méndez-Quintas et al., 2020; Rubio-Jara et al., 2016; Santonja and Pérez-González, 1984, 2001), supporting links between the Iberian Acheulean and North African LFA technical traditions (Mourre, 2003; Santonja and Villa, 2006; Sharon, 2011; Sharon and Barsky, 2016). The dating and the affinity of Revilleja with the LFA traditions place this site as an ancestor of the Iberian Acheulean documented since MIS 13 (480 ka) (Table 4). New sites and dating will help to clarify the cultural and occupational processes between MIS 16-MIS 14 in Iberia to explain the cultural relationship between Revilleja and these ~200 ka later sites.

6. Conclusions: origin and cultural phenomena of the Western European Acheulean

The dating and cultural affinities of the lithic assemblage from the Lower Gravels-Btg horizon of Revilleja de Valparaíso suggest that: 1) Western Europe in MIS 16 hosted a heterogeneous Acheulean with a dichotomous cultural and geographic origin, the southeastern Balkans for the North-Pyrenean traditions (Moncel and Ashton, 2018; Moncel et al., 2019, 2020b; Tuffreau et al., 2008) and the south of the Strait of Gibraltar for the LFA; 2) the Pyrenees from MIS 16 delimited the influences of the LFA (Méndez-Quintas et al., 2020; Santonja and Villa, 2006; Sharon, 2011; Sharon and Barsky, 2016); and 3) MIS 19 represents the genesis of the cultural processes and population growth necessary for Western Europe to host the heterogeneous technological traditions that are part of the Acheulean.

Earlier than previously thought, there were Large Flake Acheulean technological traditions crossing the Strait of Gibraltar (Alimen, 1975; Barsky and de Lumley, 2010; Freeman, 1975; García-Vadillo et al., 2023; Giles Pacheco and Santiago Pérez, 1987; Méndez-Quintas et al., 2020; Méndez-Quintas et al., 2018; Santonja and Villa, 2006; Sharon, 2011; Sharon and Barsky, 2016; Souville, 1983). Revilleja de Valparaíso marks the first appearance of LFA traditions that, in conjunction with the North-Pyrenean ones, delineate the technological multiplicity of the regional heterogeneous post-MIS 12 European Acheulean. The spatio-temporal persistence of these traditions is an important factor in the generalised technical homeostasis of the Acheulean (Finkel and

Table 4

Archaeological sites and levels (site-level) with lithic assemblages containing LCTs, dated prior to MIS 5, in the Atlantic river-basins territories of the Iberian Peninsula: use of quartzite, flint and quartz lithic raw materials, large cutting tool types and handaxes made on flake blanks. The sites were grouped into the main river basins and tributary streams drainage areas. In the Marine Isotope Stage, the symbol "/" is used to denote the existence of alternative dates for this site. In all sites where the percentages of analysed lithic raw materials (calculated over the total number of lithic industries at the site-level) and the percentages of analysed blanks used to made handaxes (calculated over the total number of handaxes at the site-level) are <100%, the percentages of used raw materials, as well as the handaxes made on flake-blanks, are approximate values. The names of some site-levels were abbreviated: Revilleja de Valparaíso-Stra. con.: Revilleja de Valparaíso-Stratigraphic context (upper + lower gravels); Santa Ana-Pl. brec.-c. & f.: Santa Ana-Pleistocene breccias-cut and fill. Other abbreviations are sorted in alphabetical order: anal.: analysed; blk.: blank; cleav.: cleaver; flk.: flake; Fl.: flint; Freq.: frequent; Hand.: handaxe; Marg.: marginal; N. pred.: no predominant; Num.: number; Pred.: predominant; Qtz.: quartz; Qtzt.: quartzite; Ref.: references; trih./pick.: thriedral/pick; Unp.: unpublished; *: published in this work.

	Marine Isotope Stage	Num. of lithics (total)	Raw mat. Anal. (%)	Qtzt. (%)	Fl. (%)	Qtz. (%)	Trih./pick. (total)	Cleav. (total)	Hand. (total)	Hand. blks. Anal. (%)	Hand. on flk.-blks. (%)	Ref.
Duero basin												
Arlanza River												
Revilleja de Valparaíso-Stra. con.	MIS 17	13	100%	100%			2		3	100%	66.7%	*
Revilleja de Valparaíso-Lower Gravels	MIS 17	10	100%	100%			1		2	100%	50%	*
Revilleja de Valparaíso-Upper Gravels	<MIS 17	3	100%	100%			1		1	100%	100%	*
Arlanzón River												
Sima de los Huesos	MIS 12	1	100%	100%					1	100%	100%	(Arsuaga et al., 1997, 2014; Carbonell and Mosquera, 2006; Demuro et al., 2019; Falguères et al., 2001a)
Galería-GIIa	MIS 13/ MIS 9-7	277	100%	33.6%	56.3%	0.7%		2	8	100%	37.5%	(Berger et al., 2008; Carbonell et al., 1999; Demuro et al., 2014; Falguères et al., 2013; García-Medrano et al., 2014, 2015)
Galería-GIIb	MIS 8-7	416	100%	18.5%	60.6%	3.6%		4	10	100%	60.0%	(Carbonell et al., 1999; Falguères et al., 2013; García-Medrano et al., 2015)
Galería-GIIa	MIS 8-7	308	100%	28.9%	50.6%	1.9%		1	5	100%	100%	(Berger et al., 2008; Carbonell et al., 1999; Demuro et al., 2014; Falguères et al., 2013; García-Medrano, 2011)
Galería-GIIb	MIS 8-7	264	100%	31.8%	43.2%	2.3%		1	14	100%	78.6%	(Arnold and Demuro, 2015; Berger et al., 2008; Carbonell et al., 1999; Demuro et al., 2014; Falguères et al., 2001b, 2013; García-Medrano, 2011)
Gran Dolina-TD10.4	MIS 11-10	247	100%	19.0%	70.0%	2.8%		1	6	Unp.	Unp.	Mosquera et al. (2024)
Gran Dolina-TD10.3-Inf.	MIS 11-10	570	100%	36.8%	43.2%	4.2%		1	16	Unp.	Unp.	Mosquera et al. (2024)
Gran Dolina-TD10.3-Sup.	MIS 11-10	666	100%	11.9%	74.3%	2.0%	1	3	2	Unp.	Unp.	Mosquera et al. (2024)
Gran Dolina-TD10.2	MIS 10-9	12747	76.8%	1.4%	73.5%	0.4%			1	Unp.	Unp.	(Arteaga-Briebe et al., 2023; Ollé et al., 2013)
Gran Dolina-Lower TD10.1	MIS 10-9	21522	100%	17.2%	60.9%	3.4%		3	9	100%	100%	de Lombera-Hermida et al. (2020)
Gran Dolina-TD10.1-A	MIS 10-9	729	100%	21.5%	65.4%	1.4%			3	100%	100%	de Lombera-Hermida et al. (2020)
Pisuerga River												
San Quirce-Level III	MIS 8-7	22602	100%	79.5%	0.9%	19.5%	3	2	1	100%	0%	(Arnáiz Alonso, 1990; Terradillos-Bernal et al., 2023)
Tormes River												
La Maya I-Zona1/Nivel IV	MIS 7	949	100%	88.0%		11.7%	3	3	12	100%	75.0%	(Demuro et al., 2024; Sánchez Yustos, 2009; Santonja and Pérez-González, 1984)
Tajo basin												
Almonda River												
Aroeira level X-Xb/c	MIS 12-11	393	100%	47.6%	5.1%	37.7%			15	Unp.	Freq.	(Daura et al., 2017, 2018)
Aroeira-Unit VII/level B2	MIS 7	170	78.8%	34.7%	2.9%	40.6%	3		16	Unp.	Unp.	(Marks et al., 2002a, 2002b; Trinkaus et al., 2003)
Salor River												
Santa Ana-Pl. brec.-c. & f.	>MIS 5	578	100%	28.0%		69.9%	6	10	47	100%	89.4%	(Carbonell et al., 2005; García-Vadillo et al., 2022)

(continued on next page)

Table 4 (continued)

	Marine Isotope Stage	Num. of lithics (total)	Raw mat. Anal. (%)	Qtzt. (%)	Fl. (%)	Qtz. (%)	Trih./ pick. (total)	Cleav. (total)	Hand. (total)	Hand. blks. Anal. (%)	Hand. on flk.-blks. (%)	Ref.
Jarama River												
Valdocarros	MIS 8-7	3009	Unp.	Yes	Pred.	Yes	Yes	Yes	Yes	Unp.	Unp.	(Heras Bastida et al., 2021; Moreno et al., 2019; Panera Gallego et al., 2011; Rubio-Jara et al., 2016; Yravedra and Domínguez-Rodrigo, 2009)
Cañaveral River												
Cantera Vieja - Nivel 1	MIS 7	3954	Unp.	Yes	Pred.	Yes		1	132	Unp.	Unp.	(Díaz Pérez, 2023; Torres et al., 2024)
Cantera Vieja - Nivel 2	MIS 7	2282	Unp.	Yes	Pred.	Yes			65	Unp.	Unp.	(Díaz Pérez, 2023; Torres et al., 2024)
Cantera Vieja - Nivel R	MIS 7	74	Unp.	Yes	Pred.	Yes			4	Unp.	Unp.	(Díaz Pérez, 2023; Torres et al., 2024)
Tajo River												
Pinedo-Unidad Inferior	MIS 8-7	1975	46.1%	41.3%	2.1%	2.7%	60	20	37	Unp.	Unp.	(López-Recio et al., 2015; Querol and Santonja, 1979, 1980)
Pinedo-Unidad Superior	MIS 8-7	3105	32.9%	23.4%	7.8%	1.6%	48	18	37	Unp.	Unp.	(López-Recio et al., 2015; Querol and Santonja, 1979, 1980)
Cien Fanegas	MIS 8	130	100%	95.4%	4.6%		43	9	19	Unp.	Unp.	(Baena Preysler et al., 2010b; Roquero et al., 2015)
Vale do Forno 8	MIS 8-7	3070	100%	74.2%	3.9%	21.9%		8	16	100%	62.5%	(Cunha et al., 2017; Mozzi et al., 2000; Raposo, 2023)
Puente Pino-PNA	MIS 6	579	100%	61.1%	6.0%	25.6%	4	2	7	Unp.	Unp.	(Rodríguez de Tembleque, 2004, Rodríguez de Tembleque, 2007)
Puente Pino-TGS	MIS 6	1051	100%	80.8%	1.0%	10.6%	3	6	7	100%	42.9%	(Rodríguez de Tembleque, 2004, Rodríguez de Tembleque, 2007)
Manzanares River												
H-02 - Nivel 4	MIS 7-6	1249	100%	0.1%	99.9%				2	Unp.	Unp.	(Álvarez Catalán et al., 2009; de los Arcos et al., 2008; de los Arcos et al., 2011; Domínguez Alonso et al., 2009; Yravedra et al., 2019)
Arriaga-IIa	MIS 5	43	100%		97.7%	2.3%		Yes	Yes	Unp.	Unp.	(López-Recio et al., 2018a; Rus and Enamorado, 1991; Rus and Vega, 1984; Silva et al., 2011)
Arriaga-IIb	MIS 5	1000	100%		100%				Yes	Unp.	Yes	(López Recio et al., 2018; Rus and Enamorado, 1991; Rus and Vega, 1984; Silva et al., 2011)
Estragales-1	MIS 5	2500	Unp.	Yes	Pred.	Yes			Yes	Unp.	Yes	(Panera et al., 2010; Pérez-González et al., 2008)
Estragales-2	MIS 5	11000	Unp.	Yes	Pred.	Yes			Yes	Unp.	Yes	(Panera et al., 2010; Pérez-González et al., 2008)
TAFESA-Nivel IV	MIS 5	464	99.8%	11.0%	61.4%	27.4%	22	2	22	86.4%	36.4%	(Baena Preysler et al., 2010a; Millán and Benítez, 2010)
Guadiana basin												
Becea River												
El Sotillo-Level 5	MIS 10-8	3202	100%	99.7%	0.2%	0.03%	7	44	59	66.1%	44.1%	Santonja et al. (2022)
Miño basin												
Miño River												
Porto Maior-PM4/MA	MIS 8-7	159	100%	91.8%		8.2%	12	9	90	100%	25.6%	(Demuro et al., 2020; Méndez-Quintas et al., 2018)
Arbo-OC1	>MIS 5	1292	100%	60.8%		36.6%	5	14	33	100%	39.4%	(Méndez-Quintas, 2020; Méndez-Quintas et al., 2019)
Arbo-OC2	>MIS 5	1850	100%	53.5%		44.2%	3	10	21	100%	42.9%	(Méndez-Quintas, 2020; Méndez-Quintas et al., 2019)
Guadalquivir basin												
Guadix River												
Solana del Zamborino	MIS 13-10	1373	100%		22.9%	77.1%	4	1	4	100%	75.0%	(Álvarez-Posada et al., 2017; Botella et al., 1976a, 1976b; Díaz-Hernández and Juliá, 2006; Jiménez-Arenas et al., 2011; López Reyes, 1998; Pinto-Anacleto, 2010)

(continued on next page)

Table 4 (continued)

	Marine Isotope Stage	Num. of lithics (total)	Raw mat. Anal. (%)	Qtzt. (%)	Fl. (%)	Qtz. (%)	Trih./pick. (total)	Cleav. (total)	Hand. (total)	Hand. blks. Anal. (%)	Hand. on flk.-blks. (%)	Ref.
Genil River												
Cueva del Ángel-level IV	MIS 9-7	747	Unp.	Yes	Pred.				4	Unp.	Yes	(Barroso-Ruiz et al., 2011; Falguères et al., 2019)
Cueva del Ángel-level VI	MIS 9-7	560	Unp.	Yes	Pred.				2	Unp.	Yes	(Barroso-Ruiz et al., 2011; Falguères et al., 2019)
Cueva del Ángel-level X	MIS 9-7	315	Unp.	Yes	Pred.				1	Unp.	Yes	(Barroso-Ruiz et al., 2011; Falguères et al., 2019)
Cueva del Ángel-level XI	MIS 9-7	115	Unp.	Yes	Pred.				1	Unp.	Yes	(Barroso-Ruiz et al., 2011; Falguères et al., 2019)
Cueva del Ángel-level XIII	MIS 9-7	272	Unp.	Yes	Pred.				1	Unp.	Yes	(Barroso-Ruiz et al., 2011; Falguères et al., 2019)
Cueva del Ángel-level XIV	MIS 9-7	142	Unp.	Yes	Pred.				1	Unp.	Yes	(Barroso-Ruiz et al., 2011; Falguères et al., 2019)
Cueva del Ángel-level XV	MIS 9-7	577	Unp.	Yes	Pred.				1	Unp.	Yes	(Barroso-Ruiz et al., 2011; Falguères et al., 2019)
Guadalquivir River												
Cerro Higoso 1-CHI-1	<MIS 15	52	Unp.	Pred.	Unp.	Unp.			1	100%	100%	(Baena-Escudero and Díaz del Olmo, 1997; Caro Gómez, 2006)
SANDO-La Cabaña-CAB1	MIS 12-8	866	100%	91.0%	8.3%		43	26	8	100%	0%	(Baena-Escudero et al., 2013, 2014, 2019, 2025)
Cantera de Pionner-PIO-1	MIS 10-8	62	100%	69.4%	25.8%				2	100%	0%	(Caro Gómez, 1993; (Caro Gómez, 2006); Caro Gómez et al., 2013)
Los Graneros - III.4	MIS 6	78	100%	96.2%	2.6%	3.8%			1	100%	0%	(Cañete-Gómez, 2017; Caro Gómez et al., 2019)
Tarazona - TAR-I2	MIS 5	568	100%	80.3%	4.9%	0.7%	8	12	9	Unp.	Unp.	(Caro Gómez et al., 2011, 2013, 2021)
Tarazona - TAR-II1	MIS 5	2885	100%	58.5%	24.2%	2.1%	5	21	45	Unp.	Unp.	(Caro Gómez et al., 2011, 2013, 2021)
Guadalete basin												
Guadalete River												
Laguna de Medina-lower section	MIS 9-8	444	39.6%	0.5%	0.7%		40	11	18	100%	0%	(Giles Pacheco et al., 1993b, 1996)
Majarromaque-basal section	MIS 7	218	Unp.	Marg.	Marg.		Yes	Pred.	Yes	Unp.	N. pred.	Giles Pacheco et al. (1993a)
Palmar del Conde	MIS 7/ MIS 5	405	Unp.	Marg.	Marg.		26	28	42	Unp.	N. pred.	Giles Pacheco et al. (1990)

Barkai, 2018; Isaac, 1976; Leakey, 1975; Nowell and White, 2012; Paige and Perreault, 2024; Sharon et al., 2011). For this to occur, accurate cultural transmission was essential (Andersson, 2011; Finkel and Barkai, 2018; Rineau et al., 2023; Shipton, 2013), both of the morphological concepts which sustain the uniformity represented by the shared types of LCTs, and of the diversity of technical procedures and typologies with equivalent morphologies that characterise the technical traditions of the regional European Acheulean (Barsky et al., 2021; Bordes, 1950, 1966, 1984; Chevrier, 2006; López-Recio et al., 2018b; Méndez-Quintas et al., 2020; Mourre, 2003; Mourre and Colonge, 2016; Santonja and Villa, 2006; Tuffreau et al., 2008; Turq, 2000).

Author contributions

F.-J. G.-V., E. C., A. B.-C., R. A.-A. and M. N.-R. were co-directors of the archaeological digs at Revilla de Valparaíso site. F.-J. G.-V., E. C. and X.-P. R.-A. designed the research and F.-J. G.-V. wrote the paper with contributions of all the authors: A. B.-C. for stratigraphy and geomorphology; R. B. for terrestrial cosmogenic nuclide dating; D. M. and I. H.-A. for electron spin resonance dating; and F.-J. G.-V., E. C., X.-P. R.-A. and A. C.-S. for lithic analysis, combined dating and review of the entire contents and structure of the paper. All authors discussed and commented on the manuscript. All data are available in the main text or the supplementary materials.

Additional information

Supplementary information accompanies this paper.

Code availability

Not applicable.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.quascirev.2026.109977>.

Data availability

All data and/or code is contained within the submission.

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