RESEARCH

Valdeprovedo open-air site: a knapping event in the early Upper Paleolithic of the Sierra de Atapuerca (Burgos, Spain)

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Abstract
In this paper, we present the site of Valdeprovedo (Sierra de Atapuerca, Burgos), an open-air Paleolithic site. This site is attractive for study and research for three main reasons. First, it is an open-air site with an extraordinarily well-preserved lithic assemblage that corresponds to a very short-lived event. Second, in this small area, refits have been achieved with a high refitting rate, which allows us to reconstruct the action carried out in this place during a specific moment, around 28 ka. And third, this is the first site of this chronology that has been documented in the Sierra de Atapuerca, providing new data on the inland population of the Iberian Peninsula by Upper Paleolithic groups.

Keywords Upper Paleolithic · Open-air site · Blade · Refit · Atapuerca

Introduction

The late MIS 3 scenario in Europe has been the subject of several discussion in recent years. The case of the Iberian Peninsula is presented as particularly interesting because it has records of the last settlements of *Homo neanderthalensis* (Straus 2022; Zilhão et al. 2017), which seemed to occur simultaneously in the final stage of MIS 3 with the first settlements of the *Homo sapiens* (Straus 2018). In the absence of human fossils, the cultural attribution of lithic industries has often been a major challenge for researchers.

Around these dates, we know of final Mousterian occupations at sites such as El Esquilleu (Baena et al. 2021);

Gorham's and Vanguard Caves (Finlayson et al. 2006; Higham et al. 2013), Carihuela (Carrión et al. 2019); Cueva Antón; and Sima de las Palomas (Zilhão et al. 2016, 2017). Sites with Chatelperronian industries attributed to Neanderthals include La Guelga (Menéndez et al. 2018), Cueva Morin (Maillo-Fernández 2005), Labeko Koba (Arrizabalaga et al. 2003), Ekain (Villaluenga et al. 2012), and Aranbaltza (Sánchez-Romero et al. 2022) (the Chatelperronian authorship is again widely discussed; see Slimak 2023). And documented sites with Aurignacian complexes that belong to *H. sapiens* include, among others, Cueva Morin (Maíllo-Fernández 2006), El Castillo (Cabrera et al. 2002), Lezetxiki (Arrizabalaga 2006; Falguerès et al. 2006), Labeko Koba, L´Arbreda, and La Viña (Santamaría, 2012; Wood et al. 2014).

This panorama has given rise to various interpretations about the end of the Neanderthals and whether they shared habitats with modern humans, leading to well-known theories such as the Ebro frontier model (Zilhão, 2000); the theory of contemporaneity or mosaic models (Straus 1996, 2003, 2005, 2009; Vaquero 2006); a hypothesis that argues displacement of populations caused by environmental changes (Finlayson 2004; Finlayson et al; 2004); the cultural continuity hypothesis (Cabrera et al. 2001); and gradual advancement of AMH populations (Maroto et al. 2005), all of which need more archaeological evidence for their verification.

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The survival and evolution of Aurignacian technocomplexes in the north of the Iberian Peninsula have been confirmed (Rios-Garaizar et al. 2013; Wood et al. 2014), as well as the fact that these extended southward, as shown by evidence in Cova de les Malladetes (Villaverde et al. 2021), Cova de les Cendres (Villaverde et al. 2019), Cova Beneito (Iturbe et al. 1993), La Boja (Zilhão et al. 2017), and Bajondillo (Cortés-Sánchez et al. 2019), before they were finally replaced by Gravettian industries as the MIS 2 horizon approached.

Several studies suggest that the populations at the end of MIS 3 were concentrated in areas of the Cantabrian and the Mediterranean coasts, probably due to the relative generosity of their ecosystems (Vidal-Cordasco et al. 2022). The relative hostility of the environment in the interior of the peninsula in this period (Vidal-Cordasco et al. 2022; Wolf et al. 2018; 2021) seems to be correlated with a lower presence of sites in these chronologies.

This population pattern continued during the Aurignacian and Gravettian, where the occupation of the coastal areas of the Iberian Peninsula predominates and sites in the interior of the peninsula are very scarce. Recently, this framework of the peninsular hinterland has been revived with contributions such as those of Cardina-Salto do Boi (Aubry et al. 2020), which has provided data from Aurignacian industries in the western part of the plateau, and Peña Capón (Alcaraz-Castaño et al. 2021), with pre-Solutrean occupations in the interior during periods of extreme conditions, with new population data by AMH from places that had traditionally been considered empty from the late Mousterian to the Magdalenian (Alcaraz-Castaño, 2023).

In this paper, we present an open-air site in the environment of the Sierra de Atapuerca, with an estimated age of 28.0 ± 1.3 ka, that can contribute with new data to this discussion, especially being the northern plateau an area with scarce evidence in these chronologies. This site is the first discovered in the Sierra de Atapuerca with an archaeological assemblage of such early dates of the Upper Paleolithic. As such, it opens the possibility of a new field of study for the research and excavation of open-air sites and the documentation of the first records of occupation in the Sierra de Atapuerca during the Upper Paleolithic afterward the population gap that exists in this territory after the end of the Middle Paleolithic.

The site

Valdeprovedo is an open-air settlement located on the northern slope of the Arlanzón River, in the vicinity of the Sierra de Atapuerca. Valdeprovedo site is located at coordinates 42.3490° (Latitude) and −3.5940° (Longitude) and 927 m.a.s.l. (Fig. 1). This position belongs to the north slope of the Arlanzón valley, which drains the NE Duero basin (N Spain). The site is situated downstream of the Sierra de Atapuerca, which lies 6 km to the East. In this area, the Arlanzón valley is carved in the Neogene sequence of the Duero basin. The slope bedrock at the site location consists of Late Miocene marls, clays, evaporates, and limestones placed at the base, which are buried by Middle Miocene sands, silts, and clays, capped with an Astaracian limestone layer which includes flint boulders and nodules (Pineda and Arce 1997). In this region, the Arlanzón valley shows a sequence of 14 fluvial terraces (Benito-Calvo et al. 2008; Benito-Calvo and Pérez-González 2015) with Early Pleistocene ages for terraces between T1 (+92–96 m) and T4 (+60–65 m); Middle Pleistocene from T5 (+50–58 m) to T11 (+12–14 m), which is located in the Middle-Late Pleistocene boundary; and Late Pleistocene for T12 (+10–11 m), T13 (+ 5 m), and probably T14 (+2–5 m) (Fig. 1; Benito-Calvo et al. 2008; Moreno et al. 2012; Arnold et al. 2013; Benito-Calvo et al. 2018).

At Valdeprovedo location, the upper part of the slope is compounded by the Middle Pleistocene terraces T5 (+50–58 m), T6 (+44–46 m), and T7 (+37–42 m), which erode partially the Astaracian limestone including flint nodules (Fig. 2). On the other hand, at the lower part of the slope, several lower terraces, lateral cones, and the terrace T14 are located (Benito-Calvo and Pérez-González 2015).

This site was discovered when lithic pieces were found in the cut of a road made in the process of creation of a science and technological park. The good preservation and workmanship of the lithic pieces motivated the intervention of this site during the 2022 excavation campaign. A small 9-m² test pit was excavated, from which a total of 187 pieces were recovered, concentrated in a small area of the pit, with a very limited spatial distribution (Figs. 2 and 3).

Methodology

Geological context

The area was recognized through geomorphological fieldwork and considering the landforms described in previous works (Benito-Calvo et al. 2008; Benito-Calvo and Pérez-González 2015; Benito-Calvo et al. 2018). Stratigraphical and sedimentological descriptions were carried out during the excavation works, carrying out granulometry and mineralogical analysis using sieve, pipette, and X-ray diffraction techniques. Besides, two samples were taken for OSL dating in the stratigraphical positions where the lithic pieces were observed during prospection works.
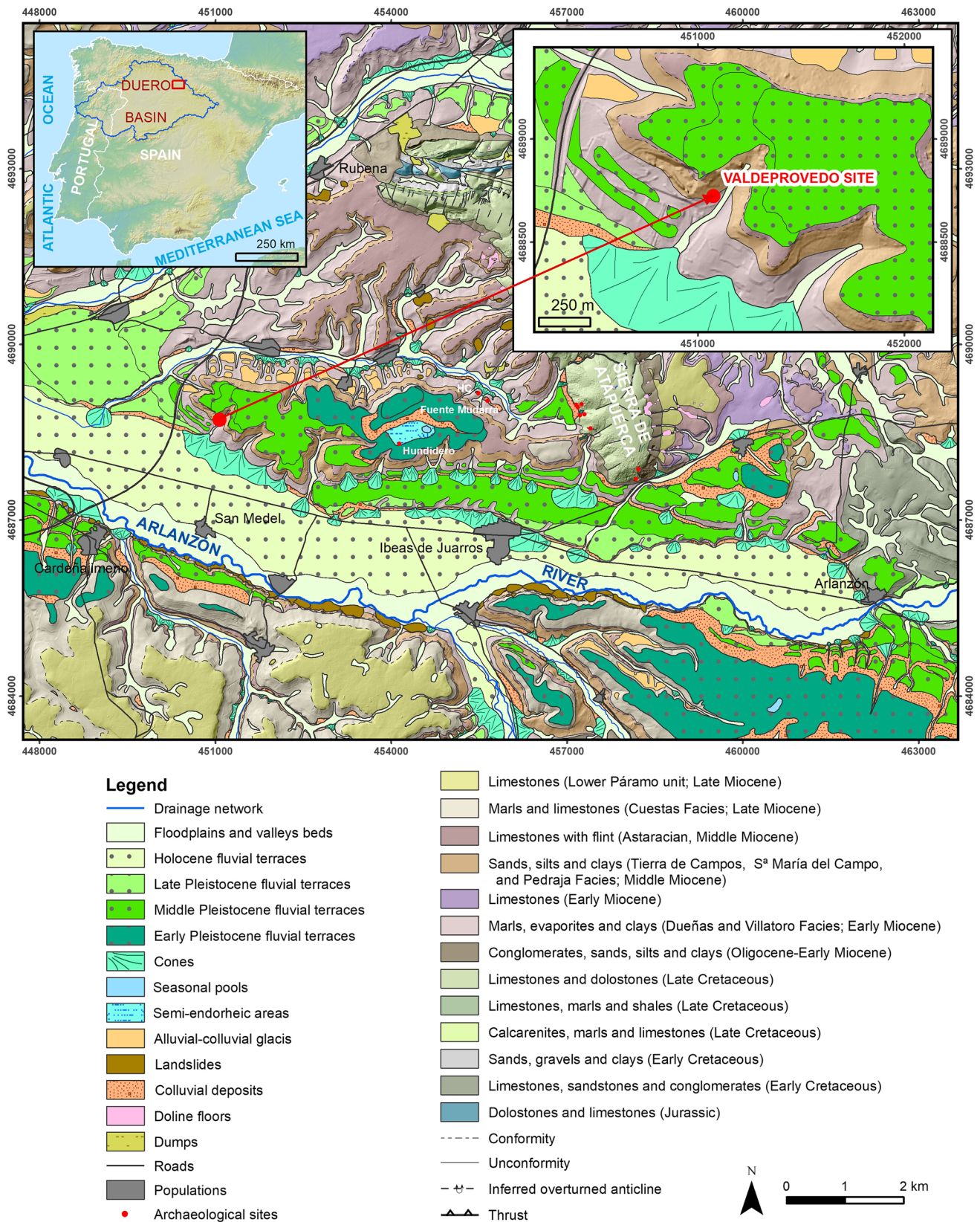
Fig. 1 Geological and geomorphological frameworks of Valdeprovedo site (modified from Benito-Calvo and Pérez-González 2015). Coordinate system: UTM ETRS89 H30N
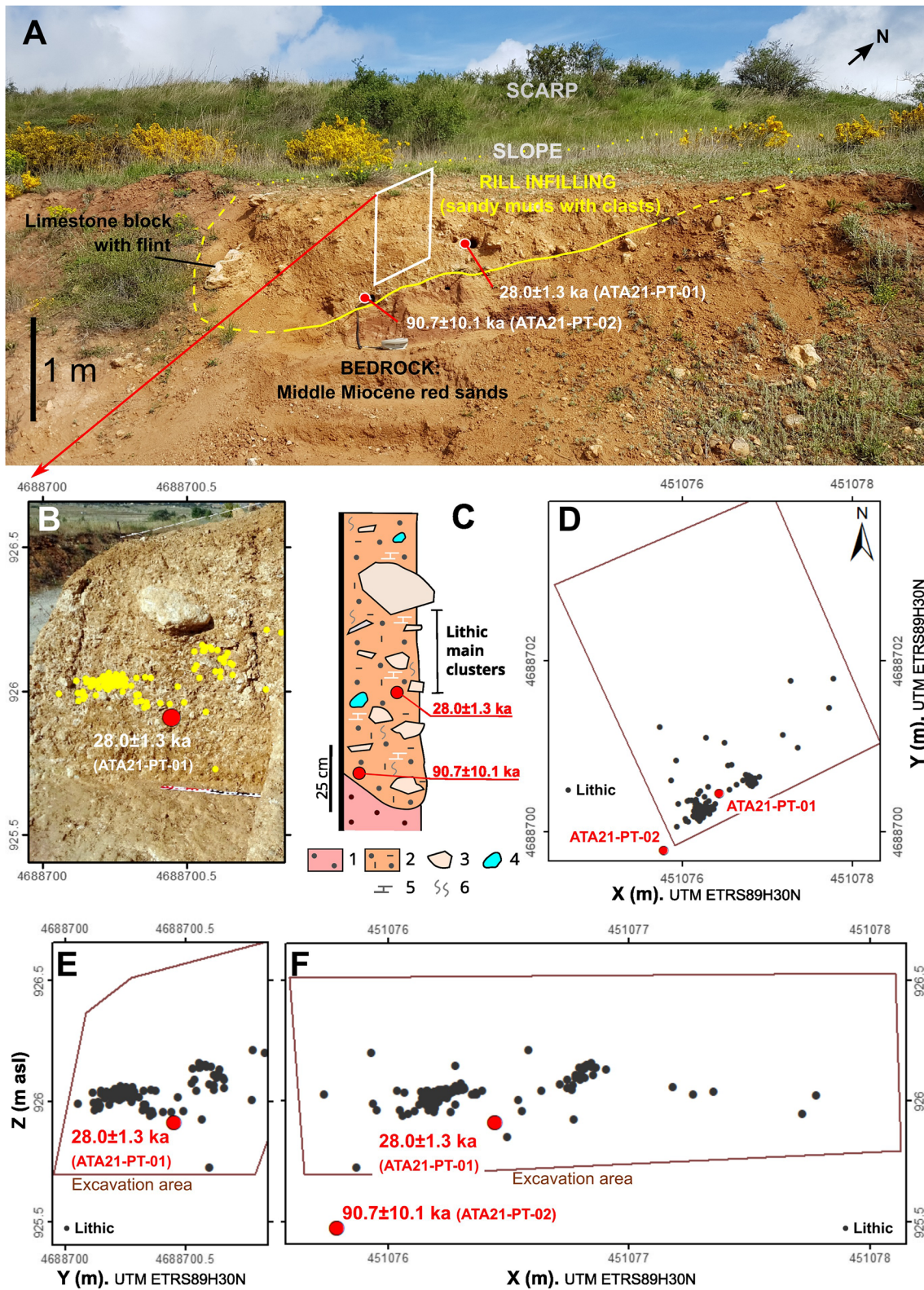
Fig. 2 Stratigraphy and spatial distribution plots in Valdeprovedo site. **A** Rill infilling on the Miocene bedrock; **B** vertical distribution of artifacts projected on the SW stratigraphic section; **C** stratigraphic column showing the OSL dates and the artifact position. Legend: 1, Middle Miocene red sands; 2, sandy muds; 3, limestone angular blocks and clasts including silicifications; 4, quartzite rounded cobbles and pebbles; 5, carbonatation; 6, root bioturbation; **D** artifact plan and OSL sampling position; **E** and **F** vertical distribution of artifacts projected on W and S sections, respectively
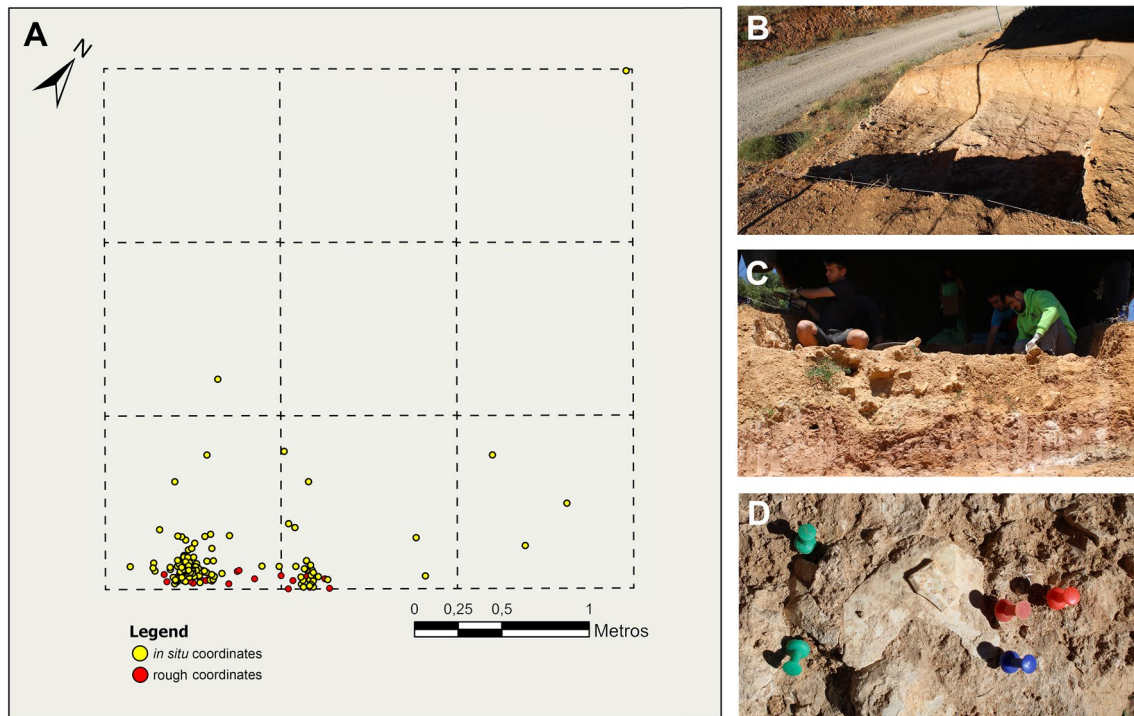
Fig. 3 A Spatial distribution of the archaeological remains. In yellow, pieces with *in situ* coordinates; in red, rough coordinates/approximate location. **B** Top view of the test pit. **C** The site during the archaeological works. **D** Detail of the discovery of lithic remains

Optically stimulated luminescence (OSL) dating

A total of two samples were collected for OSL dating from the stratigraphic units where the lithic pieces were found and previously to the beginning of the archaeological intervention. Quartz grains of sizes 180–250 μm were extracted from each sample using standard procedures (Wintle 1997). Burial doses were estimated from the OSL signal of 2-mm multigrain aliquots, measured using a single aliquot regenerative dose protocol (SAR, Murray and Wintle 2000). Dose distributions comprise the equivalent doses of 48–96 aliquots. The Central Age Model (Galbraith et al. 1999) has been applied to estimate the burial dose of sample LM21140-1. The internal-external unity approach (IEU, Thomsen et al. 2007), defined to estimate doses from incompletely bleached sediments (e.g., quartz grains which have not been exposed to sunlight enough to reset their luminescence signal prior to deposition and burial), was used instead for sample LM21140-2. Environmental dose rates were calculated as a contribution from beta and gamma radiations, determined from the concentration of radionuclides in the sedimentary matrix, and a small contribution of cosmic radiation calculated according to burial depths. The dose rate and final ages were calculated using DRAC (Durcan et al. 2015).

Logical analytical system and raw material unit analysis

The study of the lithic materials has been carried out according to the logical analytical system (LAS) (Carbonell et al. 1983, 1992, 1995, 1999, 2001; Carbonell and Mora 1986; Carbonell and Rodríguez 2002) (Table 1). To extend the analysis of the laminar products, we have resorted to other authors (Bon 2002; Santamaría, 2012) which indicate the direction of the longitudinal axis, the profile of the blades (curvature and torsion), the morphology of the cross-section, the delineation of the edges, and the direction of the negatives of the dorsal face.

In order to recognize specific activity events through the lithic record, we applied raw material unit (RMU) analysis, which attempts to reconstruct the original raw material block or nodule through the artifacts derived from it. The refits provide information on the knapping techniques employed, allow spatial inferences, and define aspects of the temporality of the occupations (Vaquero 2008).

The topographic documentation of the Valdeprovedo excavation was carried out first establishing topographic bases with centimeter accuracy using a real-time kinematic (RTK) GNSS (Leica GS15) connected to the ITACyL VRS (ETRS89H30N coordinate system), and then using these

Table 1 Categories of the logical analytical system (LAS). Adapted from Ollé et al. (2013) and Santamaría et al. (2021, 2023)

Logical analytical system	Common terms	LAS subdivision categories	Variables under study
Natural base (nB)	Pebbles, cobbles, hammers, or selected blocks	nBa: Selected and transported bases nBb: Hammerstones with percussion marks nBc: Cobble fragments with or without percussion marks	Size, shape, weight, and percussion marks
Exploitation			
First-generation negative base of exploitation (1GNBe)	Cores, cores on flakes.	1GNBe: The exploitation of a pebble or block to obtain positive bases	Volumetric concept, striking platform organization, exploitation methods, symmetry and hierarchy degree, surfaces preparation degree
Second-generation negative base of exploitation (2GNBe)		2GNBe: The positive base exploitation to obtain more positive bases (core on flake)	
Positive base (PB)	Flakes and debris	The positive bases (PBs), are the products of exploitation (flakes)	PB morphology. Direction of dorsal previous removals, angles between surfaces (Carbonell et al. 1999) (Bon 2002; Santamaría, 2012)
Fragmented positive bases (FPBs)	Broken flakes	Broken flakes; flakes with preserved point of percussion but incomplete margins	
Fragments of positive base (Frags of PB)	Flake fragments; flakes with absent butt		
Configuration			
First-generation negative base of configuration (1GNBc)	Tools on pebble, tools on flakes	1GNBc: Tools on pebble, cobble, or block 2GNBc: Tools on flakes	(Carbonell et al. 1999) Faciality, centripetal character, retouching angle, depth, mode, delineation, type, etc.
Second-generation negative base of configuration (2GNBc)			
Fragments (FRAGs)	Angular fragments		
Indeterminate (INDET)	Unidentifiable lithic items		

bases to set a total station (Leica TS15i), which was used to coordinate the archaeological findings with millimeter accuracy. The lithic pieces from Valdeprovedo were concentrated in a small sector of the excavation, and they were all of the same type of flint. To facilitate the work of refitting, they were directly spread out on a surface according to their size and category.

The recomposition of this "puzzle" was carried out according to Cattin (2002), Cziesla (1990), and Sisk and Shea (2008). These authors agree in distinguishing between different types of connections according to their origin. In this case, we use the terms refit and conjoin: refit, when the connection of pieces reconstructs a knapping sequence (a controlled conchoidal fracture), and conjoin, when the connection between pieces corresponds to fractures of non-technological origin (e.g., trampling, sediment compaction, post-depositional processes) (Sisk and Shea 2008).

Results

Geomorphological and stratigraphic framework

Valdeprovedo site is preserved in a rill or small channel filled with massive sandy muds with clasts (Fig. 2A, B, and C) which are preserved on the slope situated under the scarp of Middle Pleistocene terraces T6 and T7 (Fig. 1). The channel infilling displays a maximum thickness of 1.2 m (Fig. 2A and C), and it is carved on the Middle Miocene red sands and Early Miocene clays, following a N-S direction to converge downslope with the Valdeprovedo stream, a small lateral tributary of the Arlanzón valley (Fig. 1). Granulometry analysis using sieve and pipette techniques indicate that the matrix texture is sand silt clay (silt 41.03%, sand 33.59%, clay 25.58%) and from a mineralogical point of view is dominated by quartz (>40%), followed by calcite (40–21%), phyllosilicates (40–21%), and K-feldspar and plagioclase in proportions <5%. Sandy muds are massive and include root bioturbation and pedogenetic carbonates, together with local areas including matrix-supported clasts and blocks. The latter are composed of angular limestones with silicification areas, coming from the erosion of the Astaracian limestones, as well as quartzite rounded pebbles and cobbles coming from the upper Middle Pleistocene fluvial terraces (Fig. 2).

OSL chronology

Dose distribution of sample LM21140-1 is normally distributed, centered around 62 Gy, characterized by an overdispersion of 12% (Fig. 4a). In this case, CAM has been considered appropriate to estimate the burial dose. A subsample was artificially bleached and irradiated to a known dose.
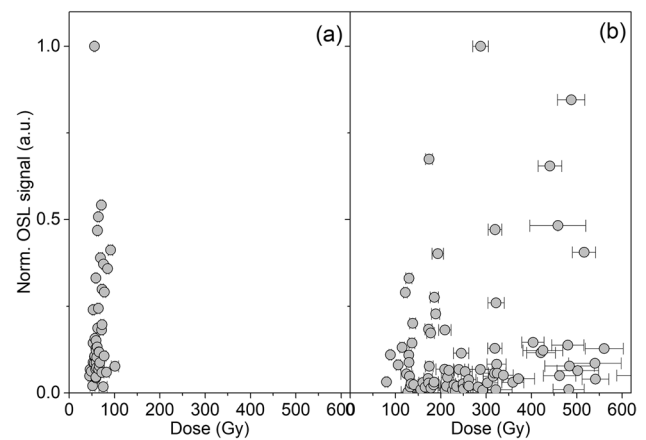

Fig. 4 Dose distributions of samples LM21140-1 (**a**) and LM21140-2 (**b**). The plots show the big differences between them. The large scatter observed on (b) is typical of a sample affected by incomplete bleaching

The derived dose distribution, where the potential extrinsic factors like incomplete bleaching or heterogeneity of the received dose have been eliminated, shows similar overdispersion. It can therefore be concluded that this sample is not affected by extrinsic factors. In contrast, dose distribution of sample LM2140-2 is highly scattered (Fig. 4b), with an overdispersion of 49%. Doses in this case range from 80 to 700 Gy, indicating the mixture of quartz grains with residual doses due to incomplete bleaching with dose that were fully bleached during transport before deposition. A minimum dose is estimated using the IEU approach, to use the part of the distribution most likely to belong to well bleached grains. Estimated doses, environmental dose rates, and derived ages are summarized in Table 2.

Archaeological assemblage

The assemblage is composed of 187 pieces, all of them Neogene flint. This type of flint is abundant in the surroundings of the Sierra de Atapuerca, where nodules or blocks of this material can be obtained in manageable and easily transportable sizes. Despite the fact that the primary outcrops are presented as large metric blocks (García Antón, 2016; Navazo et al. 2008; Navazo and Carbonell 2014), the resulting unbundle blocks are a better way of supplying raw material, in addition to notably reducing the cortical portion in the bases to be exploited.

The 187 pieces correspond to 85 complete PBs, 23 FPBs, 62 Frags of PB (of which 26 are distal transverse fragments, 17 are medial transverse fragments, and 19 are marginal fragments), and 17 fragments. As we can see, the assemblage is mostly composed of positive bases and their

Table 2 Summary of calculated dose rates, estimated burial doses, and derived ages. Sample depth, used to calculate the contribution of cosmic radiation, is also included

Sample	Lab code	Depth (m)	Dose rate (Gy/ka)			Burial dose (Gy)			Age (ka)		
ATA21-PT-01	LM21140-1	0,5	2,21	±	0,09	61,9	±	1,2	28,0	±	1,3
ATA21-PT-02	LM21140-2	1,2	1,58	±	0,06	143,2	±	15,0	90,7	±	10,1

fracture-derived categories, and there is no presence of elements such as cores or retouched pieces.

To analyze these products' characteristics, we must first consider the fragmented pieces that have been reconstructed to form conjoins.

Conjoined pieces: blade/bladelets

22+40

It is a PB with a distal fracture. Its dimensions are 61×62×12 mm. It connects with a marginal fragment of flake, which
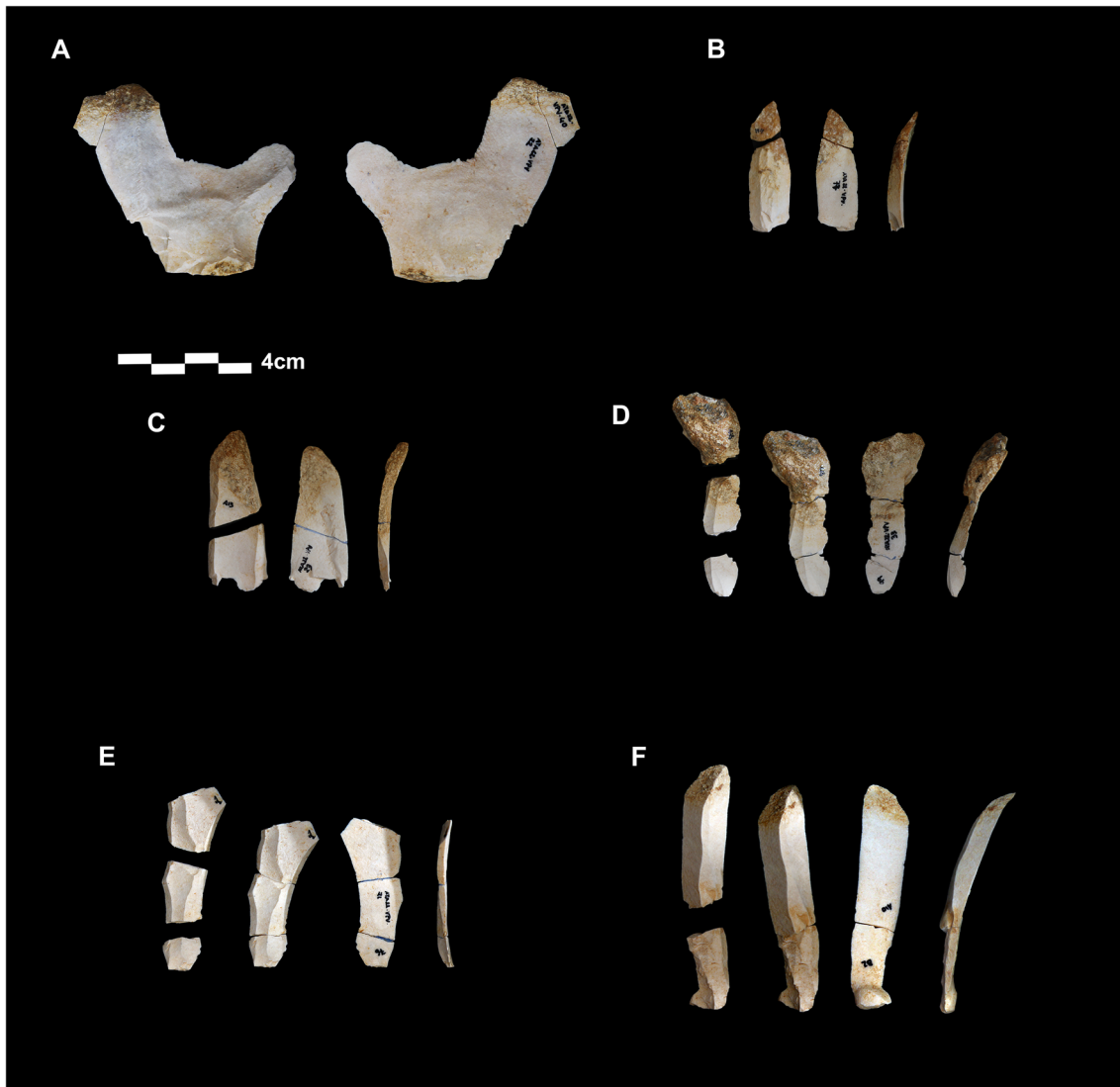

Fig. 5 Conjoined pieces

measures 21×9×2 mm. Both pieces are separated by a simple and straight fracture, probably produced by trampling (Fig. 5a).

77+111

This is a conjoin of two flake fragments, the first one is a medial transversal Frag of PB, and the second, a distal transversal Frag of PB, with a simple fracture (slightly curved/oblique).

Although we do not have the complete PB, we can see that it corresponds to a blade. This distal fragment of blade measures 38×13×x5 mm. It belongs to a blade with a rectilinear longitudinal axis, curved profile, and trapezoidal section, with convergent and negative parallel edges (Fig. 5b).

23+213

This proximal transverse FPB connects to a distal transverse Frag of PB. The fracture that separates them is clean and straight in profile.

The conjoining of both pieces forms a 44×18×3 mm blade, with a rectilinear longitudinal axis, curved profile, and trapezoidal section. The edges, as well as the negatives, are parallel (Fig. 5c).

99+33+115

This conjoin is formed by three fragments: a proximal transversal FPB, a medial transversal Frag of PB, and a distal transversal Frag of PB. They form an overshoot blade of 52×16×7mm. The fracture between the FPB and Frag of PB is shaped in *languette* form and, between the two Frags of PBs has an angular morphology, which could correspond to a bending fracture. Both may have been caused by a knapping accident due to the different flint densities in the non-cortical, intermediate, and cortical parts of the blade.

The blade's longitudinal axis veers to the left. The distal cortical part is wider and thicker due to the overshooting. With curved profile and triangular section, its edges are concave-convex, while the negatives are parallel (Fig. 5d).

76+21+117

This conjoin is formed by a proximal transversal FPB and two medial transverse Frags of PBs. The entire blade is nearly complete. In its current state, it is 45×13×3 mm. Both fractures seem to correspond to bending fractures, the more proximal one hinged the more distal one oblique (O´Farrell's type 2c). The blade's longitudinal axis veers to the right, the distal part of the PB is wider, and the curvature more pronounced to the right. Its profile is straight and the section trapezoidal. The edges are straight-concave, and the negatives are parallel (Fig. 5e).

42+210

This conjoin is composed of a proximal transverse FPB and a distal transverse Frag of PB. Together, they form a 62×13×7 mm blade. The fracture has an oblique morphology that appears to correspond to a bending fracture. The longitudinal axis is rectilinear, and the piece's profile is curved and with torsion. The cross-section is triangular, and the edges and negatives are parallel (Fig. 5f).

222+120

This conjoin is composed of a proximal transverse FPB that connects with a medial transverse Frag of PB. They are separated by a simple straight fracture (Fig. 8 (part of Set I)).

After having reconstructed some pieces from its fragments, the total assemblage comprises 178 pieces. Fracturing of lithic pieces can be intentional, or related to manufacturing processes, use, or postdepositional and taphonomical processes (Weitzel et al. 2014). In our assemblage, fractures are perpendicular to the technical axis of the flake or blade. In general, they are bending fractures, those produced when there is a force applied on a wide surface of the piece, which ends up breaking at a point (Fischer et al. 1984). According to O'Farrell (2005), O´Farrell (2004), and Santamaría (2012), these bending fractures can vary in shape, showing straight, feather, hinge, step, and *languette* morphologies, and can be related to postdepositional processes such as trampling (Boot 1987; O´Farrell 2004; Weitzel et al. 2014).

We also found abundant knapping accidents as overshoot and, to a great extent, stepped or hinged (Roche and Tixier 1982), both in the PBs themselves and in the dorsal faces of the pieces, which reveal the previous removals where these accidents occurred repeatedly. These accidents can be due to faulty knapping gestures, deficiencies in technique, or the quality of the raw material used (Roche and Tixier 1982).

Of these 178 final pieces, 89 (85 complete + 4 conjoins) correspond to PB (flakes or blades). Through their typometric analysis, we can conclude that 12 of them strictly belong to the category of blade, as their length is at least twice their width (Brézillon 1977; Tixier 1963). Seven of these are, in turn, bladelets, following the criteria established by Tixier in 1963. All of them (blades and bladelets) have parallel or subparallel edges, and edges that follow the same direction as the longitudinal axis of the piece.

Another 13 pieces can also be categorized as laminar flake (Bagolini 1968). To these are added 17 flakes, 11 wide flakes, and eight very wide flakes (Fig. 6). Using Bagolini's simplification of modules proposed by A. Arrizabalaga in 1999, based on G. Laplace's previous model, the size of the PBs can be summarized in Table 3 and Fig. 6:
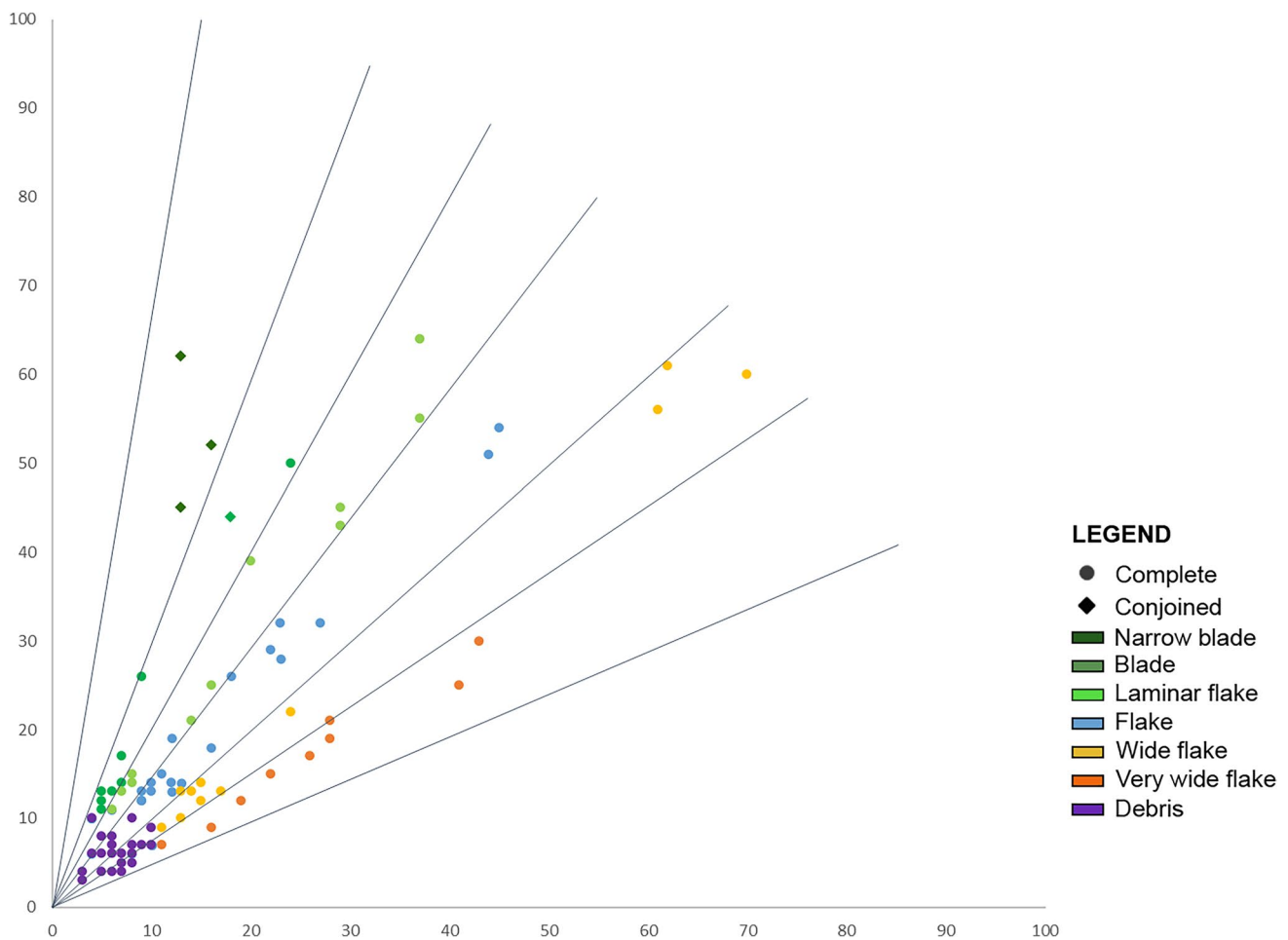
Fig. 6 Typometry of the lithic assemblage

With a length of less than a millimeter, the remaining 28 pieces have been considered knapping remains or debris (Arrizabalaga 1999).

Among the attributes of the positive bases, we can highlight the butts, categorized as platform (36% *n*=22), punctiform (8.2% *n*=5), and linear (55.7% *n*=34). At the same time, most are unifaceted (82% *n*=50) and straight (78.7% *n*=48).

In terms of corticality, 100% of the butts are non-cortical. Among the complete PBs, we observed a majority of non-cortical dorsal faces (81.9% *n*= 50), among which 4.9% (*n*=3) are cortical dominant and 13.1% (*n*=8) are non-cortical dominant, so that cortical elements amount to 18% of the whole. The preserved cortex remains coincide with the distal part of the PBs.

The PBs' dorsal faces present anterior removals, the most common being between two and four removals: 19.7% (*n*=12) present two; 29.5% (*n*=18) present three, and 16.4% (*n*=10) present four, constituting 65.5% of the total.

From the analysis of the laminar products in which it has been possible to define characteristics of the dorsal face (seven PBs and two fragments large enough to be diagnostic), we can say that the assemblage's laminar products have the dominance of the rectilinear longitudinal axis as a common factor (5/9), a profile that in the outermost blades corresponds to a curved profile (7, one of them also with torsion), while the innermost (some belonging to set A, others totally free of cortex) have a straight profile (2). The section of these laminar products is mostly trapezoidal (7), with only two triangular section blades. The edges are predominantly

Table 3 Size distribution of positive bases according to Arrizabalaga (1999)

	Big	Normal	Small	Micro	Total
Blade		2	4	6	12
Laminar flake		4	3	6	13
Flake	3	6	12	15	36
Total	3	12	19	27	61

parallel (4), followed by those categorized as convergent (3), concave-convex (1), and straight-concave (1). All the negatives (9) are parallel.

Refits

Of the total number of pieces in the assemblage, we have managed to refit 42. This represents a refitting rate of 22.4%. The connections are of the conjoin and refit types, often combined with one another (see Table 4), forming ten sets labeled A to J. Of these, set A contains the most connections, with 23 pieces.

Set A is composed of a series of flakes from a block of Neogene flint whose minimum measurements we have estimated to be 16.9 × 7 cm, from the area covered by the refitting set. Since we found a few cortical pieces and all of them belong to set A, we deduce that this nodule arrived at the site in a state of secondary decortication, with the first series used to decorticate the widest face of the nodule (series that includes pieces 32, 133, conjoin 22 + 40, 13, 109, 14, 12, 31), in which we can see remains of cortex in the distal part of the PB. These correspond to flakes and laminar flakes. After these extractions, there is a change in the orientation of the exploitation, which began to be carried out in the narrowest part of the nodule, taking advantage of the convexity created from the first series. Here, the morphology of the nodule allows for a series of laminar extractions, even with a cortical part in the first blades, which do not seem to require excessive preparation since no crested blades have been recovered. This series includes pieces 212, 211, conjoin 77 + 111, 35, conjoin 99+33+115, conjoin 23 + 213, 24, and conjoin 76 + 21 + 117.

All PBs in set A were the product of a longitudinal unipolar knapping using the longest surface of the nodule as a percussion platform, the exploited surface being the narrowest (narrow, short axis), where the extractions were carried out with a unidirectional longitudinal unipolar organization, extending around the perimeter of the nodule along the entire contour comprising the exploitation of set A (Fig. 7).

Set B is composed of two flake fragments forming a conjoin (already described in the section dedicated to this type of recompositions (Fig. 5f)). It does not connect with any other piece, so it forms a set by itself. The rest of the sets (C thru J) are recompositions of knapping events that correspond to dorso-ventral connections. One of them—set I—also includes a conjoin of the fracture of one of the flakes. These sets have the same characteristics as set A in terms of raw material, product characteristics,

Table 4 Description of the refitting sets analyzed in this study

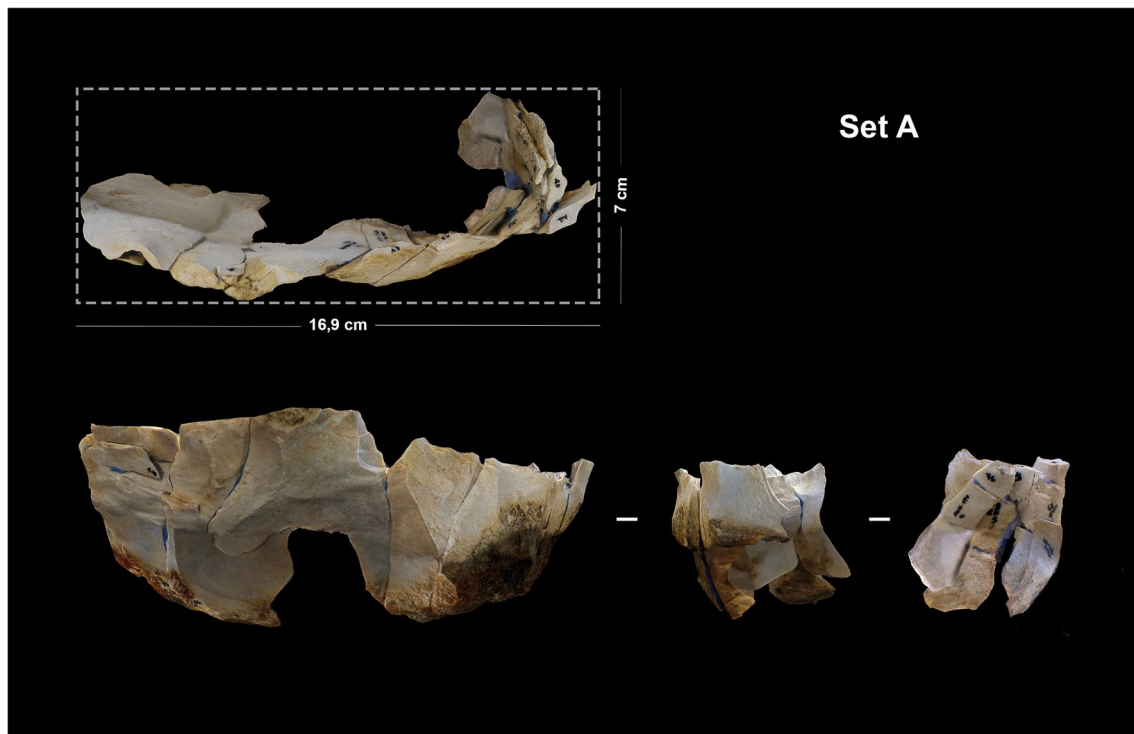| Set	Artifacts	Catalog numbers	Set type	Descriptions
A	23	32, 133, 22 + 40, 13, 109, 14, 12, 31, 212, 211, 77 + 111, 35, 99+33+115, 23 + 213, 24, 76 + 21 + 117	Refit and conjoin	Several pieces, some complete and others conjoined, form the decorticated front and first extractions of a Neogene flint nodule. Some of them have morphologies of flakes or laminar flakes, while others form a convex front used for the extraction of blades and bladelets.
B	2	42 + 210	Conjoin	Blade recomposition. FPB + distal Frag of PB. 62.1×12.3×6.5 mm. Oblique simple bending fracture. Longitudinal axis: straight. Profile: curved and with torsion. Section: triangular. Edges: parallel. Negatives: parallel. Already described in the conjoin section. (Fig. 5f)
C	2	138, 41	Refit	A blade fragment that refits on another blade. 1. PB 48.6×22×3.8 mm. Longitudinal axis: straight concave. Profile: straight. Section: trapezoidal. Edges: parallel. Negatives: parallel. 2. Frag of PB transversal distal. Same characteristics as the blade on which it refits
D	2	36, 37	Refit	Two flakes that refit, one of them FPB with simple straight fracture. The other is complete
E	2	16, 10	Refit	Two complete hinged debordant PBs
F	2	38, 39	Refit	Two complete hinged PBs
G	2	221, 229	Refit	PBF bending fracture that connects to debordant PB
H	2	86, 106	Refit	Two PB that refits. Both hinged pieces
I	3	122, 222 + 120	Refit and conjoin	Complete PB that refit with a FPB and Frag of PB conjoin
J	2	124, 11	Refit	Fragment that refits with a flake

Fig. 7 Set A in different views

and longitudinal exploitations, so we do not rule out that they belong to the same knapping sequence, even though we have not been able to reconstruct it completely with the materials available to us. Details of each set are in Table 4 and Fig 8.

The spatial distribution of this small assemblage is located in a very limited area of the test pit, in the 2 m² closest to the cut where the first pieces were seen (Fig. 9). Of the connection lines that we have been able to restore, 25 are dorso-ventral connections (refits) and eight are of conjoin type. The maximum distance between dorso-ventral connections is 41 cm, while the minimum and average is 2 cm. In the conjoin types, the maximum distance is 17 cm, and the minimum is of 1 cm. According to Ciesla 1990, connections with distances less than 0.5 m are considered short distances. Our data suggest a minimum displacement, which, together with the reconstruction of such sets as A, in which a continuous knapping sequence is linked, reflects production activities and tool configuration in a specific zone or short-term stay.

The number of connecting lines along with a representation of different sizes in this small section of the test pit indicate a rapid sedimentation, and recovery of the remains *in situ*.

Discussion

Valdeprovedo site is preserved on the north hillside of the Arlanzón valley consisting in a 1.2-m-thick channel infilling belonging to a local slope rill (Fig. 2A). The sedimentary sequence is composed of immature and poorly sorted sediments consisting of massive sandy muds (dominated by quartz, calcite, and clay minerals), which include matrix-supported coarse-grained debris consisting of limestone angular blocks and clasts, as well as rounded quartzite pebbles and cobbles (Fig. 2B and C). These characteristics indicate that the rill was filled by slope processes, such us debris and mud flows, triggered locally, which eroded and deposited the Miocene and Pleistocene fluvial deposits located in the hillside immediate surroundings. The artifacts preserved in this deposit are concentrated on the SW excavation area, being grouped in two main clusters separated in the vertical dimension by 10–20 cm (Fig. 2). The sandy muds are massive, showing no clear bedding structures informing about the sedimentation geometry, but if we assume a main horizontal sedimentation, this vertical separation could indicate that the artefacts were slightly resedimented by the flows. Nevertheless, the
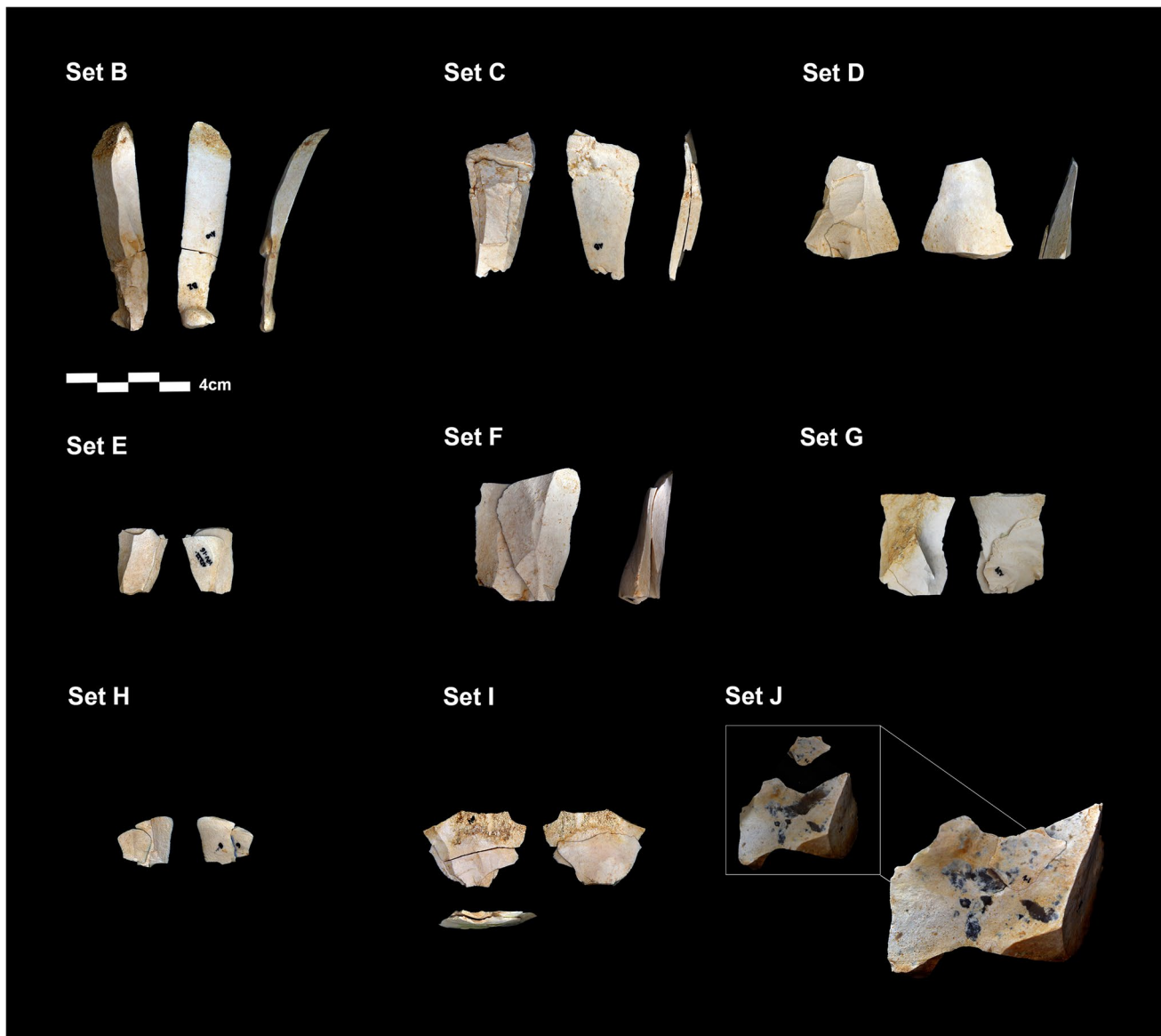
Fig. 8 Sets B to J

very local nature of the sediments, the high rate of refits, and the scarce dispersion of the material, as well as the exceptional preservation of the artifacts, indicate that the transport should be over very short distances, which also coincides with the short length documented for the rill (Fig. 2A).

The base of the sequence was dated at 90.7±10.1 ka (sample ATA21-PT-02). This sample is situated 40 cm below the main artifact clusters and very close to the Miocene bedrock, suggesting that it could incorporate poorly bleached grains coming from the bedrock. On the other hand, the sample ATA21-PT-01 was sampled in the middle of the sequence, and at a position located just at the bottom of the main artifact concentrations (Fig. 2B, C, E and F),

suggesting that 28.0±1.3 ka should be a more realistic age for the lithic accumulation.

The assemblage we have analyzed shows an example of a short-lived event that took place 28±1.3 ka years ago in the vicinity of the Sierra de Atapuerca. The OSL results for the sample collected for the deeper most sample, LM21140-2, leads to an unplausible old age. This is most likely to be due to the incomplete bleaching of the grains within that unit, carrying a residual dose. This estimated age has been discarded and is not included in any further interpretation. The low number of pieces and the density and concentration of elements, as well as their low typological variability and the refitting connections, indicate that the preservation of the record is exceptional, and the
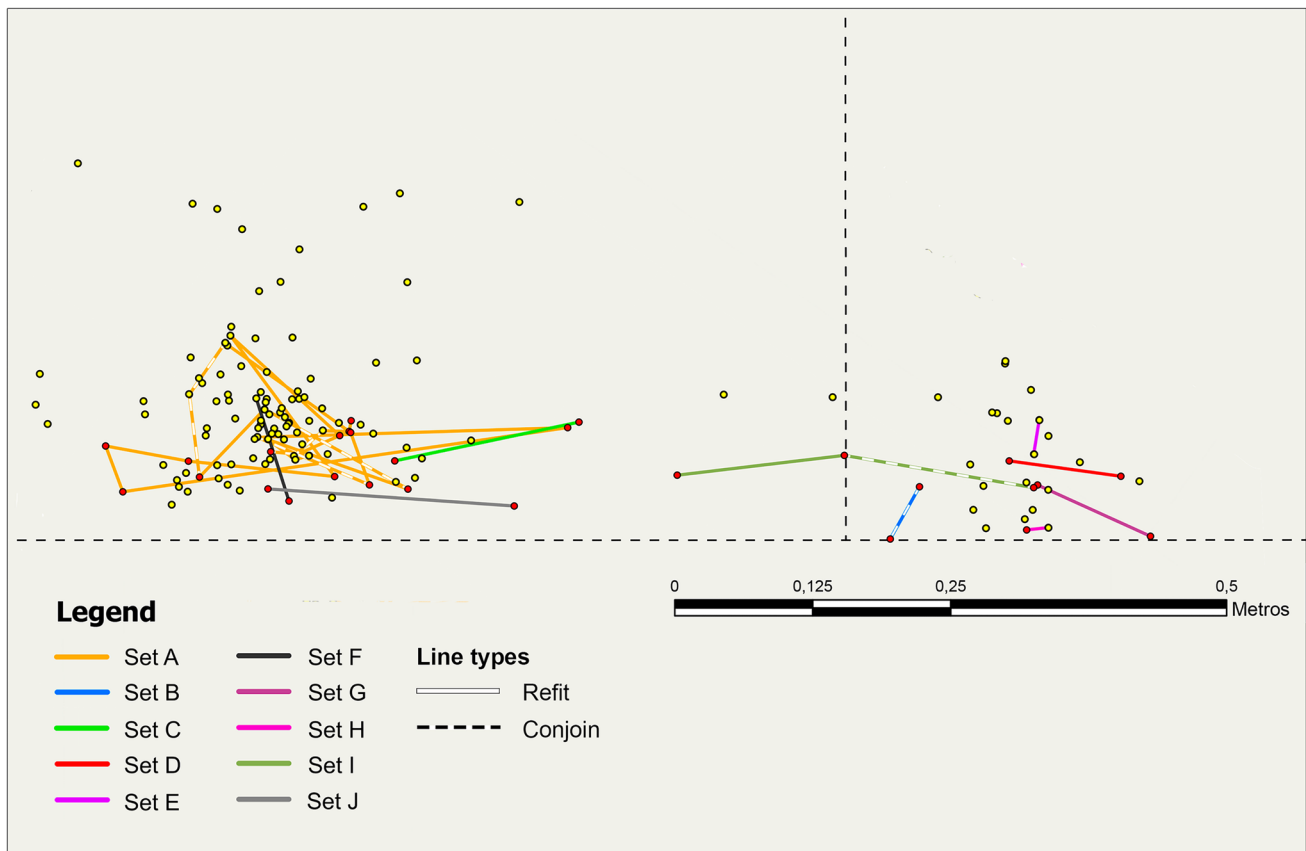
Fig. 9 Spatial distribution and refitting lines

post-depositional processes have not greatly affected the assemblage.

The raw material used is locally sourced Neogene flint, which was probably collected in the area or intentionally brought from somewhere nearby. Other open-air sites of Mousterian chronology in the Sierra, such as Hundidero (Navazo et al. 2011; Navazo y Carbonell 2014), Fuente Mudarra (Santamaría et al. 2021), and Hotel California (Santamaría et al. 2023), are examples of raw material supplies where the selection of flint blocks seems to have been made on secondary deposits located in the same place of the occupations, and the flint blocks are naturally decorticated. For this reason, we do not usually find cortical pieces. In contrast with these deposits, the corticality of several of the pieces found in the analyzed assemblage is somewhat peculiar. The first series of extractions in set A correspond to a cortex removal (see Fig. 7). These pieces are not completely cortical, but the cortical zone is reduced to the distal part of the flakes, suggesting that the nB arrives in a state of secondary decortication (Arrizabalaga 1995) and that these decorticated PBs are the ones discarded here.

The record of the Mousterian sites cited above shows that the Neogene flint sometimes presents intrusions, geodes,

and surface gelifraction. In Valdeprovedo, however, the raw material is of a more uniformly better quality, so that the Neogene flint of these pieces shows no intrusions or irregularities. This may be the reason why the original block was selected for the production that was carried out here. It is possible that the original nodule was previously tested elsewhere to check the material's quality, and the platforms were previously prepared for immediate knapping. The flint nodule knapped in this place was not abandoned at the site, or, at least, it has not been preserved in the excavated area. Perhaps, after the knapping event, the knapper took the nodule with them. However, it is also possible that the nodule was not preserved because part of the site was destroyed in the same road construction process that revealed the site. This partial destruction of the site may also be related to the separation of the two refit clusters. Since these are pieces of the same raw material, quality, manufacture, and knapping method, we assume that they are the result of the same action. Not finding all the pieces interrelated indicates that we have lost postdepositionaly some of the pieces of the knapping sequence.

Although they are basically PBs, the dorsal scars and the refitting of the pieces provide us with information

about their exploitation system. We can see how a longitudinal unipolar knapping was carried out from the upper platform of the nodule, which at first produced a series of partially cortical flakes, and then, once that side was cleared, the knapping was reoriented towards the narrowest part to produce a series of blades without the need of much preparation. This format that we have been able to reconstruct through the refitting of set A presents a very early stage of production and does not correspond to the typical Upper Paleolithic cores (prismatic, pyramidal, etc.), but the resulting products are the same as those sought with those types of exploitation. No crested blades to initiate laminar production were preserved.

The proportion of knapping debris that are smaller than 1 cm stands out. Although they could correspond to processes of regularizing and preparing cores, we cannot rule out that they were produced by retouching. However, we have not recovered any retouched pieces, so that, if these activities did indeed take place in this space, the tools produced were transported or exported elsewhere. We interpreted this operational chain based on the remains that come to us from a single stage of production, so, although we can make inferences from the rest of the stages, what we are presented with here is a fragmented operational chain.

The raw material used in the recovered Valdeprovedo pieces has the same origin and probably comes from the same block of raw material, so we can suggest that this assemblage corresponds to a single knapper, who worked on it over a short period.

The time span for the creation of this lithic assemblage is difficult to determine, but it appears to have been a single, short-lived event. Assemblages in which only lithic elements are recovered suggest short-term occupations as knapping workshops or tool reconditioning areas, depending on whether the elements recovered are related to the sourcing of raw material and core preparation or toolkit reconditioning (Turq 1989; Picin and Cascalheira 2020).

Bearing in mind characterizations developed by other authors, and despite the lack of consensus, we see that those assemblages that show the following characteristics have been traditionally classified as short term: the occupation of a small area; a low number of artifacts and a low density of remains, a high frequency of retouch; low tool diversity; short and unidirectional refitting connections; and correspond to archaeological deposits of little thickness and without spatial differentiation of activities (Bargalló et al. 2020; Clark & Barton 2017; Bicho y and Cascalheira 2020).

The site of Valdeprovedo fulfills all these characteristics except for one, the high proportion of retouched tools. Researchers such as Bicho y and Cascalheira (2020) suggest that these classifications based on isolated criteria may be inaccurate, for they do not reflect the technological choices (expedient/curated) carried out at the site.

In archaeological literature, there are examples of some sites classified as workshops in which other, complementary activities were carried out and were only discovered through traceology. In some of these places, there is a large accumulation of material as well as differentiated areas (Rios-Garaizar & Ortega 2014). In other places, the high availability of raw material in a particular place propitiated that the supplying and workshop areas are continuously revisited, as seems to have occurred in the open-air Mousterian sites of El Cañaveral Área 3, CPD30 and Parcela 32, where final tools are absent, and activities related to the learning of knapping were carried out (Baena et al. 2015). Sites with few lithic remains seem to correspond to transient activities, such as the Quinta do Saguinhal site (Almeida 2000; Bicho 2005), of Gravettian chronology, which shares many similarities with Valdeprovedo, since it was a workshop located near a raw material supply site were cobbles were exploited to obtain elongated products where the retouch index is low, and the tools are transported to another place.

The brief occupation carried out in Valdeprovedo seems to correspond more to a stop for the preparation of tools or toolkits, than to a small workshop, which authors such as Carbonell and Rosell (2004) have called opportunistic and marginal intervention centers, used for very short periods of time, or, "ephemeral places," according to Butzer (1989) who, under the criterion of the duration of the occupation, defines these sites as places occupied for a few hours or a few days.

Perhaps examples of brief knapping events such as this one do not abound because of the difficulty of their conservation and detection, but they were probably very frequent. This may also be the reason why there is no precise definition for this type of event, which is a category other than occupation. Rather, they would be vestiges of the transit and mobility of human groups through the territories that they inhabited. The Valdeprovedo site can be defined as a very specific and precise event that could have taken place in a matter of minutes. This site allows us to document an action, rather than an occupation.

The lack of diagnostic elements (blade or bladelet cores like carinated and nosed endscrapers or carinated and busked burins, and tools like Dufour bladelets or Roc-de-Combe subtype) does not allow us to make a conclusive cultural attribution of this assemblage. The OSL dates must be taken with caution since the span of 29.3–26.7 is quite wide and it must be compared with dates from other places that have been obtained with other dating methods. This leaves a range in which we could place Valdeprovedo in the Evolved Aurignacian and first Gravettian, so we will continue to refer to it as early Upper Paleolithic. We have not found other examples of this cultural period in the context of the Sierra de Atapuerca; however, the site of Valle de las Orquídeas (Mosquera et al. 2007) has similar chronologies (between

27.507 ± 2.295 years BP and 29.955 ± 2.319 years BP. TL dating in *terra-rosa* deposits), but with a lithic assemblage identified with the late Middle Paleolithic with some Upper Paleolithic features. The industry of both sites does not have elements in common in terms of nB types (large Neogene flint block in Valdeprovedo vs. small Cretaceous flint nodules in Valle de las Orquídeas); knapping method (longitudinal unipolar vs. hierarchical centripetal bipolar); or products (blades and laminar flakes without retouch vs. retouched flakes). This suggests that perhaps these TL dates are not accurate enough and raise some doubts as to whether these materials with typical Late Mousterian features could be placed in chronologies as late as those currently available.

In another site in the Sierra de Atapuerca, the Portalón cave, sublevel P11, where only a few archaeological remains were found, has been dated at 30,300±190 BP (Beta-212190). The information we have from this level was obtained from the pollen and microvertebrate remains. These reported a period preceding P11, characterized by a decrease in temperatures and increased humidity in levels P13-12, associated with a decrease in the representation of forest taxa, which was followed in levels P10-8 by a more temperate period in which the portion of forest increased and was dominated by taxa such as *Pinus, Quercus caducifolios*, and *Alnus* (López-García et al. 2010). These climactic variations would coincide in time with the limits of the dating we have for Valdeprovedo.

Within the extensive archaeological record of the Sierra de Atapuerca, this knapping stand allows us to document a period for which until now we have no archaeological evidence. This opens the door to the possibility that, as the excavations in the Sierra progress—Mirador Cave, Portalón de Cueva Mayor—we will find more remains of these first Upper Paleolithic settlers, of whom, thanks to this site, we have already been able to document their passage through this enclave, a valuable reference point within the northern plateau.

The sites with Aurignacian record in the Iberian Peninsula have a very particular geographic distribution. In the Cantabrian coast, there is a large representation of this culture from very early chronologies (from around 42,000 cal yr BP (Proto-Aurignacian) (Wood et al. 2014), as well as later phases of the Aurignacian, in sites such as La Guelga (N5-N6)(Kehl et al. 2018), La Viña (XI)(Wood et al. 2014), El Castillo (unit 18) (Cabrera et al. 2001; Wood et al. 2018), Morin Cave (5b) (Arrizabalaga 1995), Aitzbitarte III (Vb) (Marín-Arroyo et al. 2018), Bolinkoba (2inf) (Iriarte-Chiapusso & Arrizabalaga 2015), Antoliñako koba (Lmbk inf/Smk) (Aguirre Ruiz De Gopegui 2012), Labeko Koba (IV), Otero (4), and Gaztarria (cb) (Sáenz de Buruaga 1991). In the Mediterranean coast, there are examples such as L´Arbreda (G) (Maroto et al. 2012; Wood et al. 2014), Cendres (XVI) (Villaverde et al. 2019), Mallaetes (XIV-XII) (Villaverde et al. 2021), Cova Beneito

(IVb) (Iturbe et al. 1993), La Boja (OH15) (Zilhão et al. 2017), and Bajondillo (Bj13-12) (Cortés-Sánchez et al. 2019). And on the Atlantic seaboard, Lapa do Picaeiro (GG-II (GG) (Haws et al. 2020), which the rest of the Iberian Peninsula's coasts, constitutes a framework in this culture that is well represented, with sites where more than one occupation level is preserved. However, as we move inland, it is difficult to find sites in these chronologies. The evidence that we find in the Aurignacian is limited to a single site on the outer limits of the northern plateau: Cardina Salto do Boi, which preserves an open-air stratigraphic sequence documenting the transition between the Middle and Upper Paleolithic in the peninsula's interior, which also contains an Aurignacian level dated at 33.6 ± 2 ka, with a lithic industry typical of the Evolved Aurignacian with laminar knapping, Dufour and Font-Yves bladelets, and caminade endscrappers (Aubry et al. 2020).

At later dates, we find cultural parallels in the early Gravettian sites of La Viña (VII-X), Llonin (V) (de la Rasilla et al. 2020), El Cuco (III) (Rasines and Muñoz 2012), El Castillo (12) (Bernaldo de Quirós et al..., 2012), La Garma (F) (Álvarez-Fernández 2007), Antoliñako koba (Lab/Sab) (Aguirre Ruiz de Gopegui 2012), Bolinkoba (VI/F), Amalda (V-VI), and Aitzbitarte III (IV and Vsup) (Marín-Arroyo et al. 2018), which, added to the southernmost sites of Abrigo del Ángel (10b med) (Utrilla and Domingo 2001), Mallaetes (X-VII) (Villaverde et al. 2021), Cendres (XV-XVIa and b)(Villaverde et al. 2019), Nerja (NV13-11)(Sanchidrián et al. 2012), Lagar Velho (Pettitt et al. 2002, Pego do Diabo (2a)(Zilhão et al. 2010), Lapa do Picaeiro (U-Z), and Vale Boi (Belmiro et al. 2021), among others, complete the same coastal framework that we observed during the Aurignacian. Inland, we find more sites although they are still scarce. Currently we count among these examples Olga Grande 4, Cardina 1 and Foz do Medal near Cardina Salto do Boi, in the Côa Valley (Portugal), and places south of the central system, such as Peña Capón or Abrigo de la Malia (Guadalajara) (Alcaraz-Castaño et al. 2021; Alcaraz-Castaño, 2023). Promising new research projects launched in recent years have begun filling the near absolute dearth of information that had characterized this panorama.

The small assemblage recovered at Valdeprovedo 28±1.3 is a new contribution to these findings regarding the Upper Paleolithic in the peninsular interior. So far, this new site is the only evidence of these chronologies not only in the context of the Sierra de Atapuerca, but in the northern part of the interior plateau.

Conclusions

The open-air site of Valdeprovedo confirms a very small event in time and space. It is the first site with industry from the early phases of the Upper Paleolithic that has been found

in the Sierra de Atapuerca, with an estimated OSL age of 28 ± 1.3ka. The conservation of a site of these characteristics is unusual, even more so when we are talking about an open-air site. Through the study of this lithic assemblage, we have been able to record a knapping action in which the last remains of cortex from a local Neogene flint block were decorticated, and a series of tools were produced. The remains from this event have allowed us to identify an atypical exploitation of blades and the configuration of tools that were finally exported from this site. This entire sequence was produced with a single block of flint by a single knapper. "Fossilized," the event has been preserved until today to tell us about the presence in Atapuerca of populations that, until recently, were thought to have been confined to the peripheral areas of the Iberian Peninsula.

Data availability All the data used in the preparation of the article can be found in the text.

Declarations

Competing interests The authors declare no competing interests.

Ethical approval Not applicable

Consent to participate All authors have approved the manuscript.

Consent for publication All authors agree with the submission to the Archaeological and Anthropological Sciences.

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