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RESEARCH ARTICLE

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New data on chert catchment analysis in inland Iberia during the Late Pleistocene

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Abstract

In this paper, we present the first results obtained after new fieldwork and laboratory studies of chert catchment sources during the Middle and Upper Palaeolithic in inland Iberia, a region that has been traditionally depicted as marginal and sparsely populated during the last glacial due to its harsh ecological conditions compared to the coastal areas of the Iberian Peninsula. Our main aim is to determine the mobility strategies and social networks of the last Neandertals and first modern humans settled in inland Iberia and neighbouring regions, and eventually test the hypothesis that the last glacial human settlement in the Iberian hinterland was more dense and complex than previously thought. In this study, we focus on the cherts exploited at two archaeological sites: the Peña Cabra and Peña Capón rock shelters. These sites are located in the southeastern foothills of the Central System range, in the province of Guadalajara (Spain), and they have yielded a sequence of human occupations from the Middle and Upper Palaeolithic, respectively. To obtain a detailed picture of the mobility patterns and catchment strategies of the hunter-gatherers settled at these sites, our fieldwork focussed on identifying chert outcrops that could have been frequented and exploited by them. After two field seasons, 22 chert outcrops from eight geological formations were identified and more than 300 samples were collected and analysed. We conducted textural, micropalaeontological, petrographical and geochemical analyses, with the aim of comprehensively characterising the various rock resources available in the study area. Results have shown that different siliceous varieties were available in the area surrounding the sites and both Neandertals and modern humans could have provisioned there. Also, they suggest the potential existence of a network connecting the Tagus and Ebro valleys, but this is a working hypothesis to be tested with future research.

KEYWORDS
chert, field surveys, inland Iberia, Late Pleistocene, petroarchaeology

1 | INTRODUCTION

In this paper, we present the first results on lithic raw material sourcing and supply networks of the last Neanderthals and the first modern humans inhabiting inland Iberia during the last glacial. This research is based on several geoarchaeological field surveys aimed at identifying chert sources in inland Iberia that may have been used by past human groups during the Late Pleistocene. Our work is developed in the framework of the MULTIPALEOIBERIA project: *Population dynamics and cultural adaptations of the last Neandertals and the first modern humans in inland Iberia*. One of the main goals of this project is to reconstruct the territoriality, mobility patterns, and social networks of the last Neanderthals and modern humans within inland Iberia and in connection to other regions of the peninsula. To achieve this general goal, the study of lithic raw material sourcing and supply networks is a cornerstone.

In inland Iberia, the Cenozoic Madrid Basin, which comprises part of the larger Tagus Basin, has historically been conceived as an area with a large variety of siliceous rocks. These rocks are known to have been exploited by Palaeolithic societies inhabiting this part of the Iberian Peninsula, as attested by several studies (Abrunhosa et al., 2020; Bárez del Cueto et al., 2016; Bustillo & Pérez-Jiménez, 2005; Conde et al., 2000; Ortiz Nieto-Márquez & Baena Preysler, 2017). This geographical basin originated as a consequence of the uplifting of the Pyrenees and the Betic Mountain Range during the Cenozoic Alpine Orogeny. It is limited to the north and partially to the west by the Central System Mountain Range, constituted by granites and metamorphic rocks, and to the south by the Toledo Mountain Range, which shows similar lithological landscapes. To the east, the Madrid Basin is bounded by the Iberian System and the Cuenca Mountain ranges, mostly constituted by Mesozoic limestones, sands and gypsums. The Madrid Basin is mainly filled by Paleogene and Neogene deposits. Paleogene deposits crop out exclusively on the margins of the basin, whereas the Neogene (mostly Miocene) outcrops in a larger area. Both deposits include several units that are rich in silica rocks, mostly from the Miocene (Bustillo & Pérez, 2016). During the last decades of the last century, these Palaeocene and Neocene silica deposits were characterised mostly by Bustillo (M. E. Arribas & Bustillo, 1985; Bustillo, 1976, 1980), and also by Parcerisas and Tarrino (2008), Pérez-Jiménez (2010), and Baena et al. (2011). Our study aims to complete these works with new characterisations.

Inland Iberia is a key area to study human mobility during the Palaeolithic due to its geographic position and ecological variability. However, it has traditionally been depicted as a marginal, sparsely populated macroregion due to its harsh ecological conditions compared to the coastal areas of the Iberian Peninsula, especially during the cold phases of the last glacial period (Marine Isotope Stages 4 to 2) (see Alcaraz-Castaño, in press; Alcaraz-Castaño, 2015). Nevertheless, archaeological work conducted in recent years has revealed that the human settlement of inland Iberia during this period was more stable than previously thought, including the settlement of regions during the cold peak of Heinrich Stadial 2 at ~26 ka cal BP (Alcaraz-Castaño et al., 2021). The Peña Capón and Peña Cabra rock shelters have recently shown relevant results for moving forward on these topics. These sites are located in the southeastern foothills of the Central System range, in the province of Guadalajara (Spain), on the left bank of the Sorbe River, a tributary of the Henares River, which is one of the main watercourses in the Tagus basin. This basin crosses the Spanish Southern Plateau (*Meseta*) from east to west (Figure 1a). A sequence of human occupations from the Middle (Peña Cabra) and Upper (Peña Capón) Palaeolithic has been identified at these archaeological sites.

The Peña Cabra site is located in a rock shelter excavated in a vertical dolostone rock cliff on the left shore of the Sorbe River (Figure 1e). Currently, the site is 18 m above the riverbed, but it contains a 0.9 m thick fluvial sedimentary sequence overlaid by 0.6 m of a mixed alluvial and gravitational deposit rich in Middle Palaeolithic artefacts including stone tools and fragmented macromammal bones (Alcaraz-Castaño et al., 2016; Alcolea-González et al., 1997). After three archaeological seasons carried out in 1996, 2015 and 2019, 13 stratigraphic levels have been described (Figure 1f), ranging from the surface to the lowermost deposit right above the dolomitic substrate. Although Mousterian assemblages have been clearly identified in Levels 1–9, complete chronometric, palaeocological and archaeological data from this site will be published soon.

The Peña Capón site is located 1.3 km south of Peña Cabra at an altitude of 826 m asl and is 11–13 m above the current riverbed, under a dolostone rock cliff, in an area where the Sorbe valley widens and quaternary fluvial and alluvial deposits become more frequent (Figure 1b). The archaeological deposit covers a wide area of about 150 sq m along the foot of the dolostone rock wall, where 11 sq m have been excavated so far, during three field seasons (2015, 2019 and 2021) (Figure 1c). Seven archaeological levels have been identified to date, but excavation has not yet been concluded (Figure 1d). The site contains a long sequence of human occupation during the Upper Palaeolithic, including at least Proto-Solutrean and Solutrean techno-complexes, that have been dated to between ~23,800 and 26,000 cal BP. Remarkably, most of these occupations occurred during the HS2 climatic period, when environmental conditions were particularly harsh (Alcaraz-Castaño et al., 2021, 2013).

To obtain a detailed picture of the mobility patterns and catchment strategies of the hunter-gatherers settled at these sites, both Neanderthals and modern humans, it has been essential to analyse lithic raw materials. At the two sites, chert was one of the most frequently exploited rocks throughout the sequences of human occupations. Consequently, our fieldwork focussed on identifying chert outcrops that may have been frequented and exploited by these groups.

2 | MATERIALS AND METHODS

In 2018 and 2020, two field surveys were conducted in the northern part of the Southern plateau and the Central System range, with the aim of identifying and characterising chert outcrops and collecting

FIGURE 1 (a) Location of the Peña Cabra and Peña Capón sites in the central region of the Iberian Peninsula and the Sorbe River valley. (b) View of the Peña Capón rock shelter, its sedimentary deposit during fieldworks (c) and its stratigraphic sequence recorded to date (d). (e) View of the Peña Cabra rock shelter and the stratigraphic sequence recorded at the site to date (f).

chert samples for analysis. The surveying areas were chosen based on the available digital geological map of Spain, scale 1:50.000 (GEODE Project) from the Spanish Geological Survey (IGME) as well as scientific work produced by other researchers regarding the location and characterisation of chert sources. In fact, a large amount of work was conducted several decades ago, mostly in the Tagus basin (E. Arribas, 1986; M. E. Arribas & Bustillo, 1985; Bustillo, 1976, 1980), including studies in the area surrounding the two archaeological sites under study (Parcerisas & Tarrino, 2008). The geological maps and published studies enabled us to identify and select several geological units for the survey. Fieldwork was carried out over a total area of about 20,000 sq km, not with the aim of intensive prospection, but simply to visit areas that contained chert according to the geological charts. The main area encompassed the Upper Tagus River basin and some of its tributaries (e.g., Sorbe, Jarama, Henares and Badiel rivers) between the Central System and the southern sub-Plateau. We also surveyed some areas located to the north of the Central System as well as some regions west of the Iberian System range. These areas nowadays belong to the provinces of Guadalajara, Madrid, Ávila and Segovia.

During the field surveys, 22 outcrops were identified and described. For each of them, a file describing its main characteristics was created in a database. Samples were collected in an attempt to obtain a complete picture of the outcrop's internal variability by collecting at least 15 samples per outcrop. These were first analysed macroscopically to define the visual and micropalaeontological characteristics of each sample and to identify macroscopic variations within a given outcrop. The macroscopic characterisation was performed using an Olympus SZ61 stereoscopic microscope (from 6.7 to ×45 magnification) with an internal light source. Images were taken using a coupled Olympus SC30 camera. We also considered the overall knapping aptitude based on the rocks' general texture, grain size and homogeneity, as well as the absence or presence of microfractures and fissures and the size of nodules. Afterwards, two samples from each outcrop were selected for petrographic analyses. A total of 44 thin sections were made at the *Servei de Làmina Prima* laboratory at the University of Barcelona, with thicknesses ranging between 25 and 30 µm. These were then analysed using an Olympus BX41 petrographic microscope (from 40 to ×400 magnification).

Then, geochemical analyses were conducted to quantify the chemical composition of cherts. For this study, we selected 65 samples from five chert outcrops from the same geological unit. The aim was to test whether it was possible or not to establish differences between outcrops appearing at the same geological formation based on the macroscopic similarities between samples collected at different outcrops. Thus, if we are able to observe differences among outcrops appearing in the same geological unit, then, the next stage will be to include all the geological sources. High-resolution inductively coupled plasma-mass spectrometry (HR-ICP-MS) was applied. Analyses were performed at the Laboratory of Elemental and Isotopic Geochemistry for Petrological Applications (labGEOTOP) at the Spanish National Research Council research institute 'Geosciences Barcelona' (GEO3BCN-CSIC) using an HR-ICP-MS Thermo Scientific Element XR system. For the loss on ignition test, powdered samples (0.5 g) were heated in a furnace for 9 h at 1000°C following the method described by Lechler and Desilets (1987). Powdered samples were dried at 40°C for 24 h. Powdered samples (100 mg) were then acid digested in closed polytetrafluoroethylene vessels with a combination of $HNO_3 + HF + HClO_4$ (2.5:5:2.5 mL vol/vol). The samples were evaporated and 1 ml of HNO_3 was added to perform double evaporation. Finally, the resulting sample was topped up to 100 mL with 1% HNO_3 (vol/vol) with MilliQ water (18.2 MΩ cm^{-1}).

To improve the ICP-MS sensitivity, we used a tuning solution containing 1 µg L^{-1} Li, B, Na, K, Sc, Fe, Co, Cu, Ga, Y, Rh, In, Ba, Tl and U and 20 mg L^{-1} of a monoelemental solution of ^{115}In as internal standard. The detection limit was calculated as three times the standard deviation of the average of 10 blanks. The precision of the results (±1.5) was expressed in terms of two standard deviations from a set of eight reference material measurements (reference materials: Andesite JA-2 and Basalt JB-3). The accuracy value (>96.8%) was calculated using the absolute value of the difference between the measured values obtained during analysis and the certified values from a set of eight reference material analyses (JA-2 and JB-3). In this study, 49 isotopes were analysed: ^{23}Na,^{24}Mg, ^{27}Al, ^{31}P, ^{39}K, ^{43}Ca, ^{49}Ti, ^{54}Fe, ^{55}Mn (expressed as % oxides), ^{7}Li, ^{9}Be, ^{45}Sc, ^{51}V, ^{52}Cr, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{66}Zn, ^{69}Ga, ^{74}Ge, ^{85}Rb, ^{88}Sr, ^{89}Y, ^{90}Zr, ^{93}Nb, ^{98}Mo, ^{120}Sn, ^{121}Sb, ^{133}Cs, ^{137}Ba, ^{139}La, ^{140}Ce, ^{141}Pr, ^{146}Nd, ^{147}Sm, ^{151}Eu, ^{157}Gd, ^{159}Tb, ^{162}Dy, ^{165}Ho, ^{166}Er, ^{169}Tm, ^{174}Yb, ^{175}Lu, ^{178}Hf, ^{181}Ta, ^{208}Pb, ^{232}Th, ^{238}U (expressed as µg/g).

3 | RESULTS

3.1 | Geological units containing chert

Twenty-two chert outcrops from eight different geological units were identified during fieldwork (Figure 2 and Table 1). Below, we describe the main features of cherts from each formation.

1. Cherts embedded within limestones and marls containing fauna from the Lower Oligocene (Unit 53 from the IGME Geode 50, Z1700) (López Olmedo et al., 2022). In the Paleogene sediments that constitute the sedimentary refilling of the Tagus Tertiary basin, there are several chert levels. There is a group of fine-grained yellowish-to-white limestones that include chert levels, which are well arranged in layers of 0.30–1 m and alternate with levels of greenish to reddish marls, locally including gypsum (Adell Argiles et al., 1978). Nodular cherts appear embedded within limestones with gastropods, ostracods and *charophyte algae* that usually appear with evidence of bioturbation that is dating from the Lower Oligocene (M. E. Arribas & Bustillo, 1985). An outcrop with grey to white nodular cherts with a medium level of knapping potential was identified in the vicinity of Huérmeces del Cerro (Guadalajara province), where evidence of knapping was also found.
2. Chert originated in limestones and marls containing sponge spicules from El Pedregal formation (Aalenian—Bajocian, Jurassic) (Unit 166 from the IGME Geode 50, Z1700) (López Olmedo et al., 2022). In the studied area, the Jurassic extends filling the preceding Triassic sedimentary basin, and it is divided into four formations: the Carniolan formation or dolomitic basal section, the intermediate limestones, the marly-limestones section and the upper limestones. Cherts appear on the roof of the carnioles, embedded in levels of sandy limestones (Bascones et al., 1979; Parcerisas & Tarrino, 2008). One chert outcrop embedded within these limestones and marls from El Pedregal formation was identified near the town of El Pedregal. Chert appeared stratified and was highly tectonized, with extremely low knapping potential, at least in the surveyed outcrop.
3. Cherts embedded within dolomites, dolomitic limestones and marls from the Carnian—Ladinian (Triassic) (Unit 134 from the IGME Geode 50, Z1700) (López Olmedo et al., 2022). The lithostratigraphic units from the Muschelkalk are mainly constituted by a series of dolomites, sandy dolomites and dolomitic marls. In the dolomitic levels appear nodular cherts from different morphologies and generally of small size, having been observed in

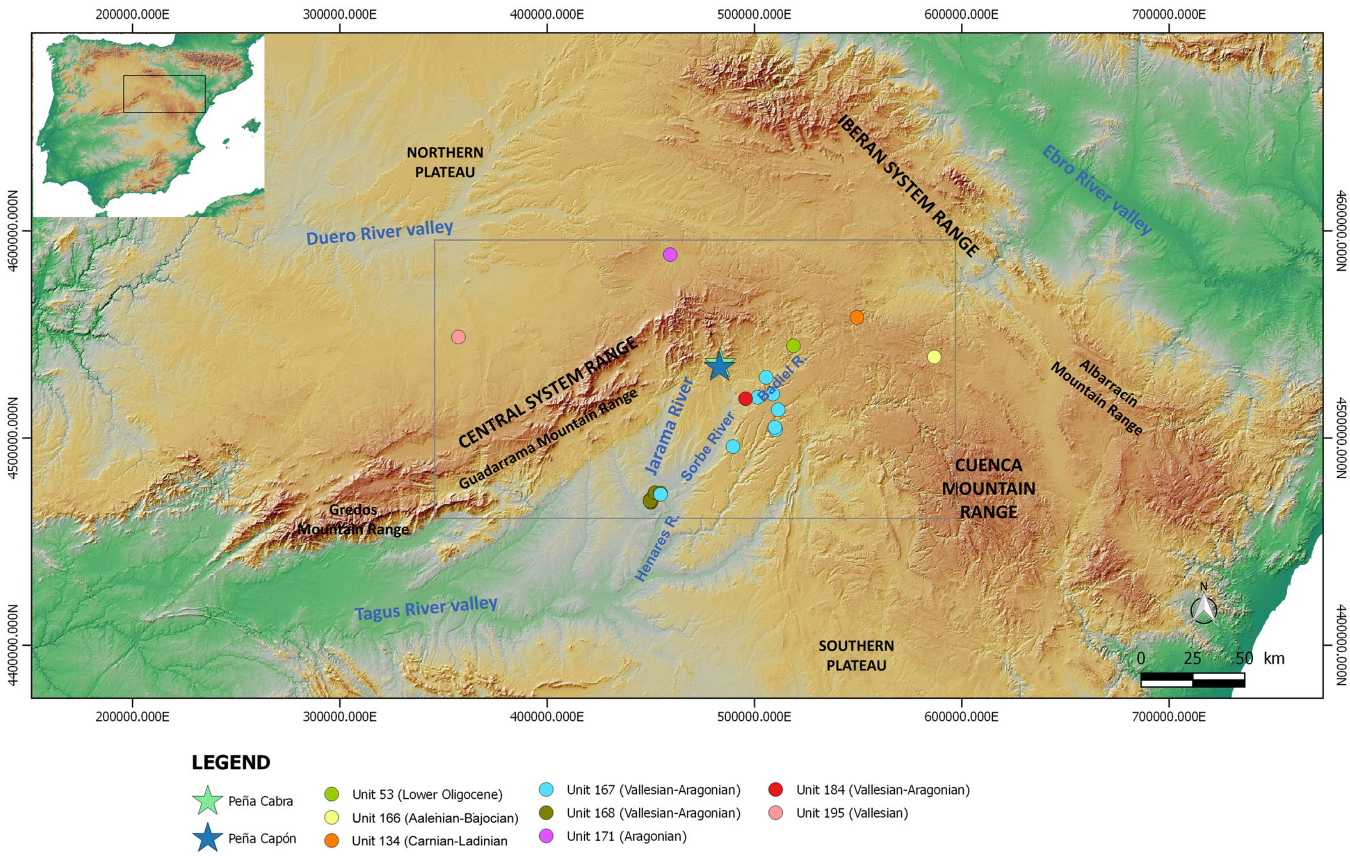

FIGURE 2 Main location of the outcrops analysed in the framework of this paper. The grey square indicates the research area studied using bibliographic information.

levels that oscillate between 2 and 4 cm up to 10–12 cm thick (Lendínez González et al., 1987; Parcerisas & Tarrino, 2008). Blueish nodular cherts measuring 10–20 cm were identified near the town of Lodares (Guadalajara province): these were highly fissured and tectonized, and their exploitation during prehistoric times would have been almost impossible.

4. Cherts appearing within limestones and dolomites from the Vallesian—Aragonian (Miocene) (Unit 167 from the IGME Geode 50, Z1700) (Aznar Aguilera et al., 1984; López Olmedo et al., 2022; Portero García et al., 1983). In the Madrid basin, the Miocene appears in three large sedimentary stages: the Lower Unit, the Middle Unit and the Upper Unit (Bustillo & Pérez, 2016). Within the Intermediate Unit, chert nodule horizon appears embedded with multicoloured clays and some local carbonates (Baena et al., 2015). This unit possesses tuffaceous limestones, microcrystalline limestones and dolomitic limestones with textures of replacement of evaporates by carbonates and chert, outcropping with thicknesses from 15 to 80 m (Aznar Aguilera et al., 1984; Parcerisas & Tarrino, 2008). Eight chert outcrops were identified within the dolomites and limestones from this unit, largely outcropping in the Upper Tagus River basin, near the towns of Gajanejos, El Sotillo, Romancos, Muduex, Brihuega and Jadraque (all in Guadalajara province). Chert nodules are abundant and can measure up to 40 cm. Their colours vary from brownish to whitish and they mostly present a medium to high knapping potential. Evidence of knapping was found at some outcrops (e.g., Muduex, Brihuega and Romancos).
5. Cherts embedded within limestones from the Vallesian—Aragonian (Miocene) (Unit 168 from the IGME Geode 50, Z2400) (Montes et al., 2022). In the Madrid basin, the Intermediate Unit from the Miocene also presents cherts originated by the dissolution of the original carbonates and replacement of silica (Bustillo & Pérez, 2016; Goy Goy et al., 1986). Eight chert outcrops in this geological unit were studied, all of which were located close to the Manzanares and Jarama rivers, near the Madrid districts of Berrocales, Cañaveral and Vallecas and the town of Coslada (Bárez del Cueto et al., 2016). Chert is abundant and appears as large, predominantly grey nodules, with a medium to high knapping potential.
6. Cherts originating in limestones from the Lower Páramo (Aragonian, Miocene) (Unit 171 from the IGME Geode 50, Z2300) (Pineda et al., 2022). In the limestones and marly limestones from the Lower Páramo Unit, chert nodules appear embedded in masses of up to 6 m of very varied colour schemes (García-Cortés et al., 1993; Parcerisas & Tarrino, 2008). Abundant chert nodules embedded within these limestones were found near the village of Alconada de Maderuelo. Two macroscopic varieties were

TABLE 1 Reference sample, outcrop, formation, age and a number of samples studied per outcrop.

Reference	Outcrop	Municipality	Province	Formation	Age	Macro	TS
HUE	Huérmeces del Cerro	Huérmeces del Cerro	Guadalajara	Unit 53	Lower Oligocene	15	2
PED	El Pedregal	El Pedregal	Guadalajara	Unit 70	Aalenian—Bajocian	15	2
LOD	Lodares	Medinaceli	Soria	Unit 126	Carnian—Ladinian	15	2
JAD-A	Jadraque A	Jadraque	Guadalajara	Unit 167	Vallesian—Aragonian	15	2
JAD-B	Jadraque B	Jadraque	Guadalajara	Unit 167	Vallesian—Aragonian	15	2
RO	Romancos	Romancos	Guadalajara	Unit 167	Vallesian—Aragonian	15	2
RO-2	Romancos 2	Romancos	Guadalajara	Unit 167	Vallesian—Aragonian	15	2
BRI	Brihuega	Brihuega	Guadalajara	Unit 167	Vallesian—Aragonian	15	2
GA	Gajanejos	Gajanejos	Guadalajara	Unit 167	Vallesian—Aragonian	15	2
MU	Muduex	Muduex	Guadalajara	Unit 167	Vallesian—Aragonian	15	2
SOT	El Sotillo	Guadalajara	Guadalajara	Unit 167	Vallesian—Aragonian	15	2
COS-FI	Coslada—San Fernando I	Coslada	Madrid	Unit 167	Vallesian—Aragonian	15	2
CA-HU	Cañaveral—El Humedal	Coslada	Madrid	Unit 168	Vallesian—Aragonian	15	2
CA-32	Cañaveral—Parcela 32	Coslada	Madrid	Unit 168	Vallesian—Aragonian	15	2
VA-VI	Vallecas—Víctor	Vallecas	Madrid	Unit 168	Vallesian—Aragonian	15	2
BEN	Berrocales Norte	Madrid	Madrid	Unit 168	Vallesian—Aragonian	15	2
CDP30	CDP30	Madrid	Madrid	Unit 168	Vallesian—Aragonian	15	2
CA-3	Cañaveral—Área 3	Coslada	Madrid	Unit 168	Vallesian—Aragonian	15	2
CV-BE	Cantera Vieja—Berrocales	Coslada	Madrid	Unit 168	Vallesian—Aragonian	15	2
ALC	Alconada de Maderuelo	Alconada de Maderuelo	Segovia	Unit 171	Aragonian	15	2
HI	Hita	Hita	Guadalajara	Unit 184	Vallesian—Aragonian	15	2
ARE	Arévalo	Arévalo	Ávila	Unit 195	Vallesian	15	2

Abbreviations: Macro, macroscopic analysis; TS, thin section—microscopic analysis.

identified, one of which was opaline and white, while the other was a greyish variety with a medium knapping potential.

7. Cherts originating in limestones from the Vallesian—Aragonian (Miocene) (Unit 184 from the IGME Geode 50, Z2400) (Montes et al., 2022). Also belonging to the Intermediate Unit from the Miocene in the Tagus river basin, chert appear embedded in limestones from the Vallesian—Aragonian (Aznar Aguilera et al., 1984) One chert outcrop belonging to this Miocene formation was identified near the town of Hita. Chert presented in the form of medium to large whitish nodules with a medium knapping potential.
8. Cherts embedded within limestones from the Arévalo formation (Vallesian, Miocene) (Unit 195 from the IGME Geode 50, Z2300) (Pineda et al., 2022). The Arévalo formation is constituted by sandy limestones with intercalated marls that originated in a lacustrine environment, with thicknesses that can reach up to 70 m. These limestones locally present chert concentrations in nodules or thin layers (Carreras Suárez et al., 1979). One chert outcrop belonging to this Miocene formation was identified near the town of Arévalo. Cherts presented in the form of small, brownish nodules with a medium knapping potential.

3.2 | Macroscopic and petrographic analyses

At least 15 samples from each identified outcrop were macroscopically described and the textural and micropalaeontological content were defined. Then, thin sections from two samples per outcrop were prepared and petrographic analyses were performed. Below we describe the main features of cherts from each geological unit. The overall knapping aptitude of each of them is also considered (Figure 3 and Table 2).

1. Cherts from Unit 53 (limestones and marls with fauna, Lower Oligocene). These present a mudstone-type smooth texture with only a few metal oxide inclusions. The raw material is characterised by the absence of bioclastic content, as these cherts originated in a hypersaline sedimentation environment. They

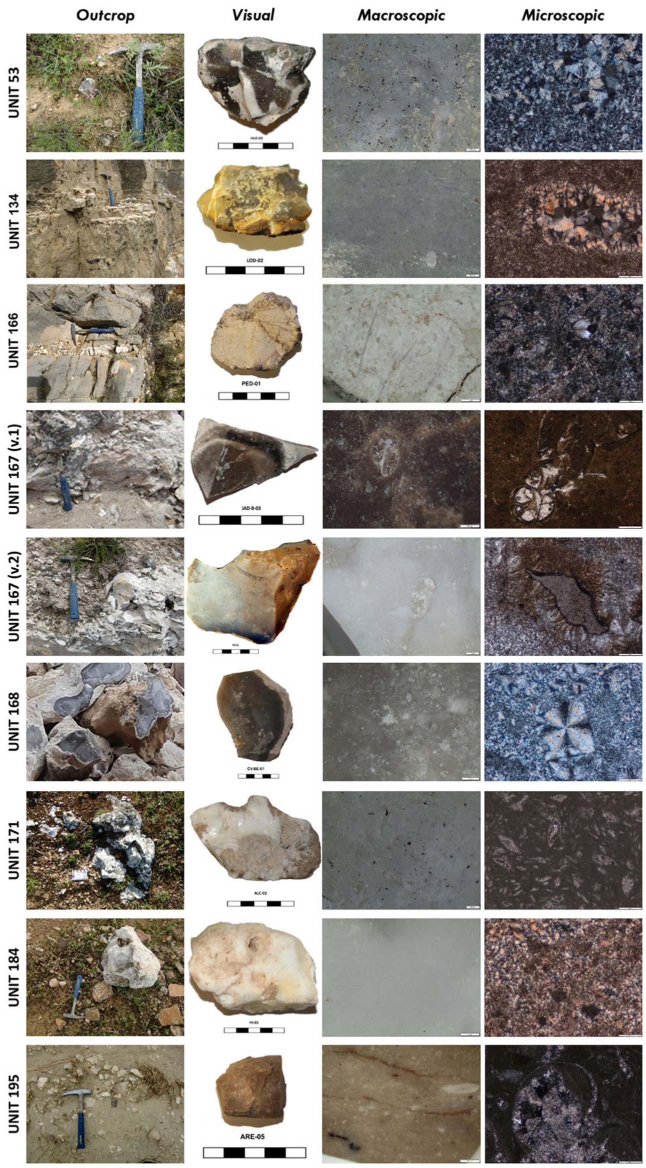

FIGURE 3 Outcrops' detail, visual, macroscopic and petrographic views for each geological unit.

possess a medium knapping potential. Under the petrographic microscope, the main texture was revealed to be a microquartz fabric with macroquartz cementations and porosities.

2. Cherts from Unit 166 (El Pedregal limestones, Aalenian-Bajocian). Macroscopically, these cherts are of mudstone to wackestone-type textures with metal oxide inclusions. Phantoms of bioclastic remains were observed. They appear highly tectonised and would be almost impossible to knapp. At the microscopic scale, a microcryptoquartz fabric is the main texture with length-fast chalcedony in the pore-filling. Metal oxides, carbonate relicts and detrital grains are also observed.
3. Cherts from Unit 134 (dolomites, dolomitic limestones and marls, Carnian-Ladinian). These cherts appear embedded within dolomitic limestones and are highly tectonized, with consequently low knapping potential. The macroscopic texture is mudstone-type, with inclusions limited to what is probably organic matter and bioclastic remains (probably microforaminifera), having originated in a marine sedimentary environment. Observation under a petrographic microscope revealed that a microcryptoquartz fabric is the main texture with length-slow chalcedony and macroquartz cementations, as well as a few carbonate relicts.
4. Cherts from Unit 167 (limestones and dolomites with chert, Vallesian-Aragonian). Two different macroscopic textures were identified within cherts from this unit, so their features will be described separately.
   - Variety 1. This was identified in the Jadraque A and Coslada-San Fernando outcrops, two of the eight outcrops assigned to this formation. The samples present a varied texture with metal oxide and micritic residues and *Charophyte algae* and gastropods as the main micropalaeontological content. These cherts possess a medium to high knapping potential, depending on the sample. They originated in a lacustrine sedimentary environment. Observation at the petrographic scale revealed that they are in fact limestones in the process of silicification by microcryptoquartz fabric. Metal oxides and detrital components are also preserved.
   - Variety 2. This is the predominant variety, found in six of the eight outcrops ascribed to this unit. These cherts possess a medium to high knapping potential and are macroscopically characterised by mudstone-type textures with metal oxide and gypsum pseudomorph inclusions. There is no bioclastic content because these cherts originated in a hypersaline continental environment. Viewed under a petrographic microscope, the textures vary widely depending on each outcrop. Microcryptoquartz fabric generally forms the predominant texture, but opal still remains in several outcrops (in the case of Berrocales Norte, it is still the main texture). The presence of opaline textures within these cherts indicates young silicifications. Length-fast and length-slow chalcedony are also present as cementations in a number of outcrops.
5. Cherts from Unit 168 (limestones with cherts, Vallesian-Aragonian). These cherts possess a mudstone to wackestone-type texture with metal oxide and carbonate remains as the main inclusions. They originated in a hypersaline continental environment, and so there is no bioclastic content. The knapping potential of these cherts is high. Observation under the petrographic microscope revealed differences between the outcrops. The microcryptoquartz fabric is often the main texture, but in some samples opal is still the predominant component. Ancient porosities are filled by length-fast and length-slow chalcedony as well as macroquartz, and metal oxide and carbonate relicts were also observed.
6. Cherts from Unit 171 (limestones from the Lower Páramo, Aragonian). These cherts have a mudstone-type texture with metal oxides and lenticular gypsum pseudomorphs as inclusions.

TABLE 2 Main macroscopic and petrographic texture of each analysed outcrop.

			Macroscopic texture					Microscopic texture									
Ref	Outcrop	Unit	Cortex	Texture	Inclusions	Fossils	Sed. Envir.	MAQ	MIQ	−CA	+CA	OP	CAR	OX	EV	DE	POR
HUE	Huérmeces Cerro	53	Limestone	Mudstone	Oxydes	–	Evaporithic	5%	88%	–	–	–	4%	1%	–	–	2%
LOD	Lodares	134	Dolomite	Wackestone	Oxydes Inertite	Microforam?	Marine?	1%	95%	–	1%	–	3%	–	–	–	–
PED	El Pedregal	166	Dolomite	Wackestone	Oxydes	Microforam?	Marine?	–	83%	2%	–	–	9%	5%	–	1%	–
JAD-A	Jadraque A	167	Marl	Mudstone	Oxydes Carb. Rem	–	Evaporithic	–	7%		2%	–	–	90%	–	1%	–
JAD-B	Jadraque B	167	Marl	Wackestone	Oxydes Carb. Rem	Charophytes Gastropods	Lacustrine	1%	50%	3%	–	2%	40%	1%	–	–	3%
RO	Romancos	167	Limestone	Mudstone	Oxydes		Evaporithic	–	83%	6%	–	1%	3%	–	6%	–	1%
RO	Romancos 2	167	Limestone	Mudstone	Oxydes	–	Evaporithic	2%	88%	4%	–	–	2%	1%	3%	–	–
BRI	Brihuega	167	Limestone	Wackestone	Oxydes Gypsum Inertite	–	Evaporithic	–	47%	–	39%	2%	3%	3%	6%	–	–
GA	Gajanejos	167	Limestone	Mudstone	Oxydes	–	Evaporithic	–	82%	3%	–	7%	3%	1%	2%	–	2%
MU	Muduex	167	Limestone	Mudstone	Oxydes	–	Evaporithic	–	53%	1%	–	38%	4%	–	4%	–	–
SOT	El Sotillo	167	Limestone	Mudstone	Oxydes	–	Evaporithic	–	86%	–	1%	4%	4%	1%	4%	–	–
COS-FI	Coslada-S. Fernando I	167	Limestone	Wackestone	Oxydes Carb. Rem	Charophytes	Lacustrine	2%	15%	1%	–	74%	7%	1%	–	–	–
CA-HU	Cañaveral-El Humedal	168	Limestone	Mudstone	Oxydes Carb. Rem	–	Evaporithic	1%	26%	4%	–	65%	3%	1%	–	–	–
CA-32	Cañaveral 32	168	Limestone	Wackestone	Oxydes Carb. Rem.	–	Evaporithic	2%	87%	–	4%	–	7%	–	–	–	–
VA-VI	Vallecas- Víctor	168	Limestone	Wackestone	Oxydes Carb. Rem	–	Evaporithic	13%	81%	–	–	–	5%	1%	–	–	–
BEN	Berrocales Norte	168	Limestone	Wackestone	Oxydes Carb. Rem	–	Evaporithic	1%	29%	2%	–	61%	5%	2%	–	–	–
CDP30	CDP30	168	Limestone	Mudstone	Oxydes	–	Evaporithic	3%	73%	1%	–	15%	7%	1%	–	–	–
CA-3	Cañaveral Área 3	168	Limestone	Wackestone	Oxydes Carb. Rem	–	Evaporithic	1%	42%	4%	–	45%	7%	1%	–	–	–

TABLE 2 (Continued)

Ref	Outcrop	Unit	Macroscopic texture: Cortex	Texture	Inclusions	Fossils	Sed. Envir.	Microscopic texture: MAQ	MIQ	−CA	+CA	OP	CAR	OX	EV	DE	POR
CV-BE	C. Vieja Berrocales	168	Limestone	Mudstone	Oxydes Carb. Rem	–	Evaporithic	–	44%	5%	–	42%	7%	2%	–	–	–
ALC	Alconada Maderuelo	171	Limestone	Mudstone	Carb. Rem	–	Evaporithic	–	–	1%	–	17%	75%	1%	5%	–	1%
HI	Hita	184	Limestone	Mudstone	–	–	Evaporithic	–	49%	1%	–	38%	4%	–	7%	–	1%
ARE	Arévalo	195	Marl	Wackestone	Oxydes Carb. Rem	Charophytes Gastropods	Lacustrine	1%	22%	–	–	1%	69%	5%	–	2%	–

Abbreviations: −CA, length-fast chalcedony; +CA, length-slow chalcedony; CAR, crbonates; DE, detrital remains; EV, evaporitic remains; MAQ, macroquartz; MIQ, microquartz; OP, opale; OX, oxydes; POR, porosities.

The bioclastic content is absent, as these cherts originated in a hypersaline continental sedimentation environment. Examination under a petrographic microscope revealed that these samples are in fact limestones in the process of silicification by opal. Lenticular gypsum pseudomorphs were also observed during the petrographic analysis, as well as some porosities. Despite not being entirely silicified, these cherts present a high knapping potential due to the volume of the nodules and the absence of internal fractures.

7. Cherts from Unit 184 (limestones, Vallesian-Aragonian). These cherts possess an azoic mudstone-type texture, without any evidence of mineral inclusions or bioclastic remains being detected during macroscopic observation. The sedimentation environment was a hypersaline continental lagoon and the samples present a medium knapping potential, as they contain some internal fractures as well as porosities. Observation under a petrographic microscope showed that the main predominant fabric is microcryptoquartz and opal. Length-fast chalcedony was observed filling ancient porosities and lenticular gypsum pseudomorphs are also abundant.
8. Cherts from Unit 195 (Arévalo limestones, Vallesian). These cherts, which possess a brownish colour that clearly differentiates them from the other studied cherts, present a wackestone-type texture, with metal oxides and carbonate remains as inclusions. *Charophyte algae* and gastropods represent the main bioclastic content. They originated in a continental lacustrine environment and present a medium knapping potential due to the presence of some internal fractures. At the petrographic scale, limestone can be observed in the process of silicification by a microcryptoquartz fabric. Carbonate remains are abundant and siliceous textures often appear in the pore-filling of ancient porosities (e.g., the internal structure of the bioclastic remains). Metal oxides and detrital grains are also abundant in the thin sections.

3.3 | Geochemical analyses

Geochemical analyses were performed to determine whether it was possible to differentiate between outcrops from the same formation according to elemental chemical composition. To this end, we studied 65 samples from five different outcrops from the same geological unit, selecting cherts from limestones and dolomites from the Vallesian—Aragonian (Unit 167 from the IGME Geode 50). The following outcrops were studied: Jadraque 1 (N: 10), Jadraque B (N: 10), Romancos (N: 15), Brihuega (N: 15) and Muduex (N: 15). Powdered samples were analysed by HR-ICP-MS. We identified 49 isotopes, although 9 of them presented values below the equipment's limits of detection in most of the samples (^{133}Cs, ^{147}Sm, ^{151}Eu, ^{157}Gd, ^{159}Tb, ^{165}Ho, ^{166}Er, ^{174}Yb, ^{175}Lu) (see Supporting Information Raw Data).

A principal component analysis (PCA) was run with the following elements (Li, V, Co, Ni, Zn, Rb, Sr, Y, Pb and U), as the descriptive

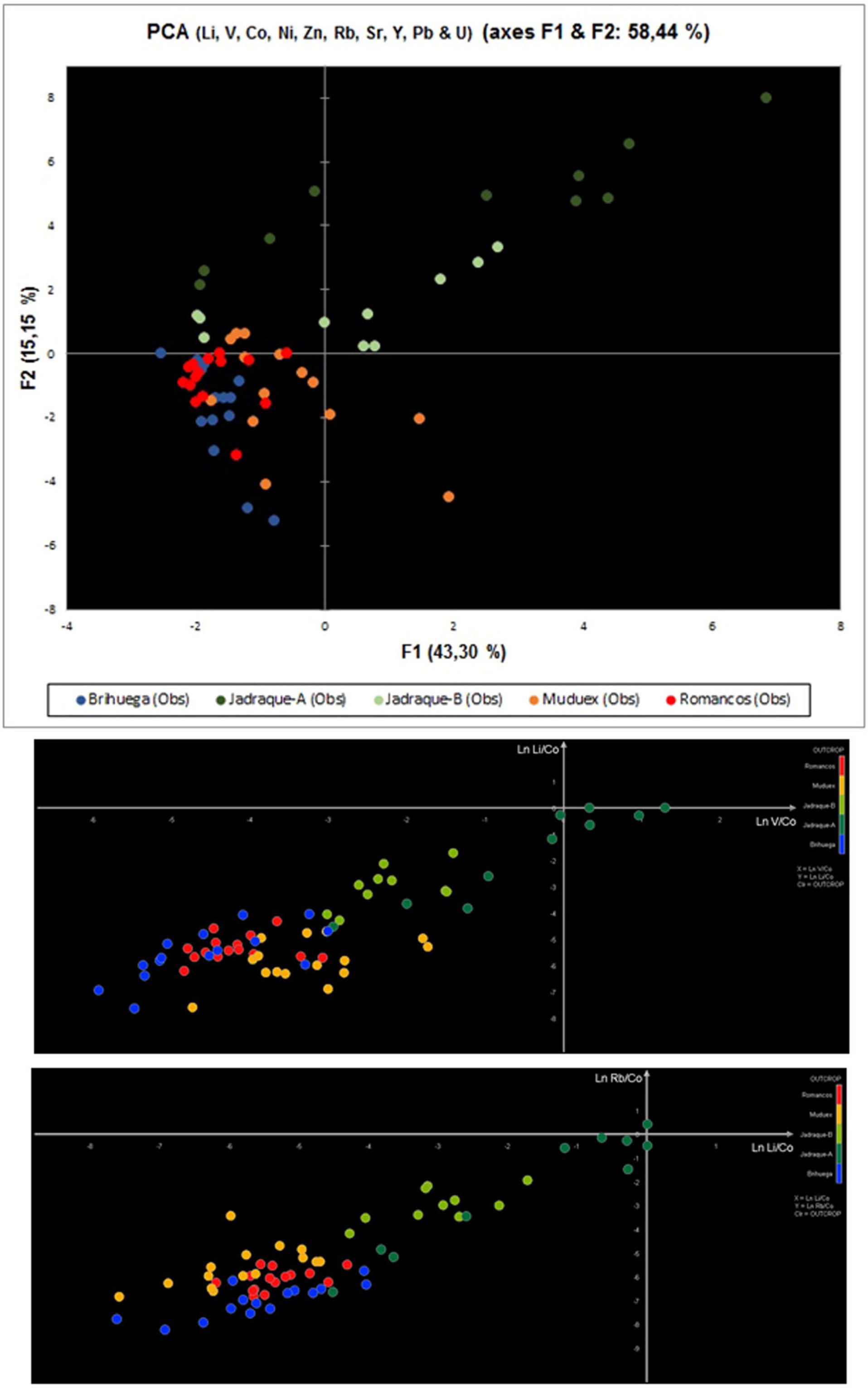

FIGURE 4 Principal component analysis (PCA) plot (top) and scatterplots with Ln Li/Co versus Ln V/Co values (middle) and Ln Rb/Co and Ln Li/Co (bottom) for LA-ICP-MS data with the geological samples from Unit 167 outcrops of Brihuega, Jadraque-A, Jadraque-B, Muduex and Romancos. LA-ICP-MS, laser ablation-inductively coupled plasma-mass spectroscopy.

statistics indicated that these were the elements with higher standard deviation between sources (Figure 4, top). The PCA was calculated using XLSTAT software (Addinsoft, 2022), and F1 (15.15%) and F2 (43.30%) explained 58.44% of the total variance. Samples from Jadraque A and Jadraque B outcrops can easily be distinguished from the other outcrops. However, it was not possible to establish solid differences between the samples from Brihuega, Muduex and Romancos, which appeared to overlap.

Next, the scatterplot concerning Ln V/Co versus Ln Li/Co (Figure 4, middle) showed that it was not possible to clearly distinguish between outcrops, as most of the samples appear overlapped. In a similar way, the scatterplot showing Ln Li/Co versus Ln Rb/Co (Figure 4, bottom) was not conclusive, as the overlapping area still remained present. Thus, the first approach to quantify the elemental chemical composition of evaporitic cherts from the same geological unit was not conclusive. Future studies are needed to try to observe if at least it is possible to establish differences at the elemental compositional level between outcrops belonging to different geological formations.

3.4 | Archaeological data: First results from Peña Cabra rock shelter

We performed a macroscopic analysis of 530 chert samples from the Peña Cabra rock shelter, of which 123 samples were collected at Level 1, 181 at Level 2, 4 at Level 3, 6 at Level 4, 8 at level 5, 168 at Level 7 and 40 at Level 8. Macroscopic observation enabled us to identify four siliceous varieties (Figure 5), besides an indeterminate group, composed of 32 samples without specific features or too altered to be analysed. Below, we summarise the main macroscopic features of the identified varieties.

Type 1 is the most abundant chert type at all archaeological levels, in a proportion generally above 80%. The macroscopic texture of this whitish chert type is quite smooth, and it contains only a few metal oxides inclusions together with some lenticular gypsum pseudomorphs. The bioclastic content is absent, as these cherts originated in a hypersaline continental sedimentation environment.

Type 2 is represented by only six samples and was only detected in the most recent levels (1–3) and in Level 7, always in a low proportion (1–2 samples per level). This chert type is brownish with a wackestone to packstone-type texture and is characterised by metal oxides, micritic residues and detrital quartz grains as inclusions, with *charophyte algae* and gastropods forming the main micropalaeontological content. These cherts originated in a lacustrine sedimentation environment.

Type 3 was only identified in Levels 1 and 2, with just one sample per level, rendering it an extremely rare chert type which is characterised here in accordance with the features observed in these two samples. These reddish-to-blackish cherts have a packstone-type texture dominated by an abundance of metal oxides and probable organic matter. The micropalaeontological content presents an abundance of sponge spicules and probable microforaminifera which was not possible to identify due to the poor state of preservation. The micropalaeontological content reveals that these cherts originated in a marine sedimentation environment.

The last variety identified by macroscopic analysis is a jasper, which appears in the most recent levels of the archaeological

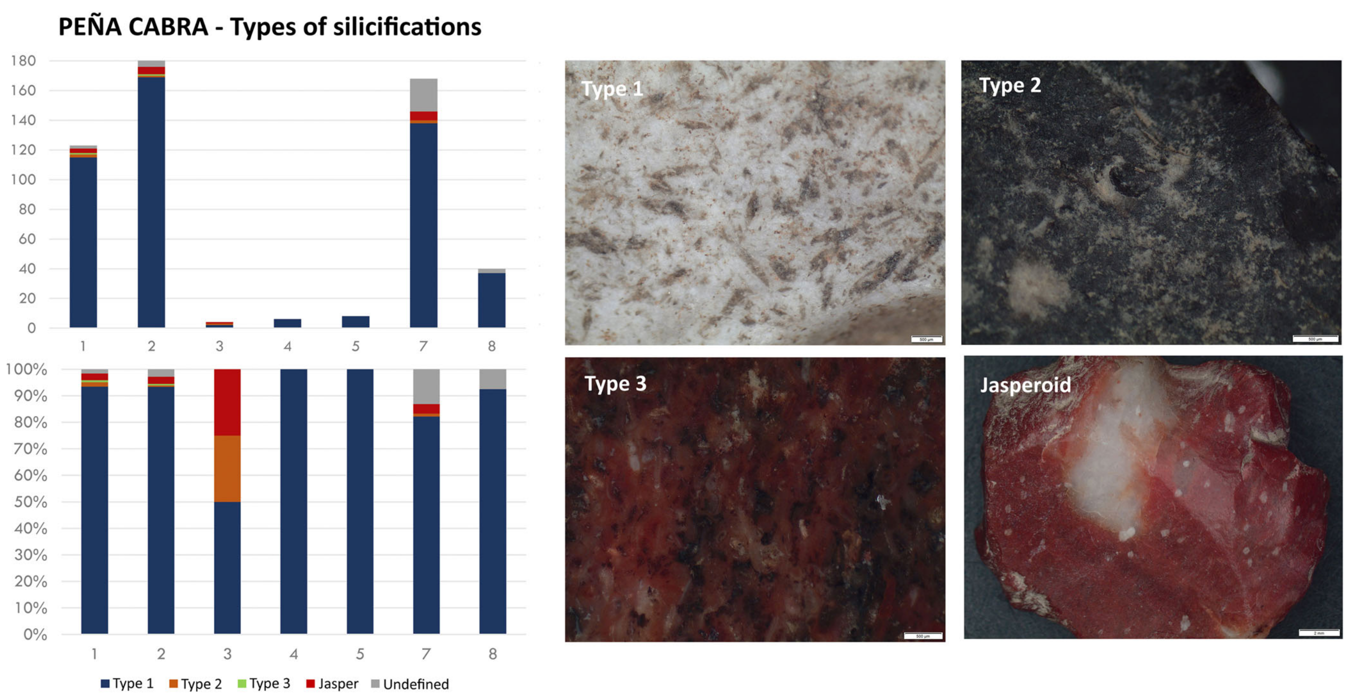

FIGURE 5 Graph with the averages of each chert type from Peña Cabra distributed by levels and macroscopic detail of the four siliceous varieties.

sequence (1–3) and in Level 6. These orange-to-reddish cherts present smooth surfaces with blackish spots that could correspond to amorphous organic matter or metal oxide, being the main inclusion content.

3.5 | Archaeological data: First results from Peña Capón rock shelter

A total of 996 chert remains recovered during the archaeological seasons at the Peña Capón rock shelter have been studied macroscopically. Of these, 930 samples come from the Middle Solutrean levels (315 from Level 1, 152 from Level 2a, 314 from Level 2b and 149 from Level 3), whereas 24 chert remains were recovered at the pre-Solutrean occupation documented in Level 4 (most probably Proto-Solutrean), and the remaining 42 samples come from Levels 5–6 (24 samples in Level 5 and 18 in Level 6), tentatively assigned to the Gravettian (see Alcaraz-Castaño et al., 2021 and forthcoming papers for discussion on cultural attributions). Macroscopic observation enabled the identification of five different types of chert (Figure 6), besides an indeterminate group composed of 22 samples without specific features or too altered to be analysed. Below, we describe the main macroscopic features of the five different chert types.

Type 1 is the most abundant variety, with 851 samples being ascribed to this group. Macroscopically, this whitish chert shows a quite smooth mudstone-type texture, with scarce metal oxides as inclusions. Lenticular gypsum pseudomorphs are also observed as inclusions. This chert type is characterised by the absence of bioclastic content, as it originated in a hypersaline continental sedimentation environment.

Type 2 is represented by 33 samples and is found on almost all levels (the exception being Level 5) in similar proportions (between 1% and 5%). This reddish-to-brownish chert type has a mudstone to wackestone-type texture. Bioclastic content is absent, as these cherts originated in a hypersaline sedimentation environment, but micritic residues and metal oxides are abundant.

Type 3 is formed by 14 samples and was detected in all the Middle Solutrean occupations except for Level 2b (5 samples in Level 1, 5 in Level 2a and 4 in Level 3), but not in the pre-Solutrean occupations (Levels 4–6). This light brownish to whitish chert type can be macroscopically defined as having a mudstone azoic texture, without inclusions of bioclastic remains, as it originated in a hypersaline sedimentary environment. The only inclusion that has been observed consists of some blackish spots that might correspond to amorphous organic matter.

Type 4 is composed of 49 samples, which were collected from all archaeological levels with the exception of Level 5, in proportions that range from 1% to 20% depending on the Level (6 samples from Level 1, 5 from Level 2a, 31 from Level 2b, 1 from Level 3, 5 from Level 4 and 1 from Level 6). Macroscopically, this brownish chert presents a varied texture, with metal oxides, micritic residues and detrital quartz grains as inclusions. *Charophyte algae* and gastropods constitute the main micropalaeontological content, as these cherts originated in a lacustrine sedimentary environment.

Finally, the macroscopic analysis identified 27 jasper samples, which were only detected in the Middle Solutrean occupations (two samples from Level 1, 4 from Level 2a and 21 from Level 2b). This orange-to-reddish siliceous variety presents extremely smooth surfaces. Blackish spots that could correspond to metal oxides or amorphous organic matter are abundant in some samples, and the

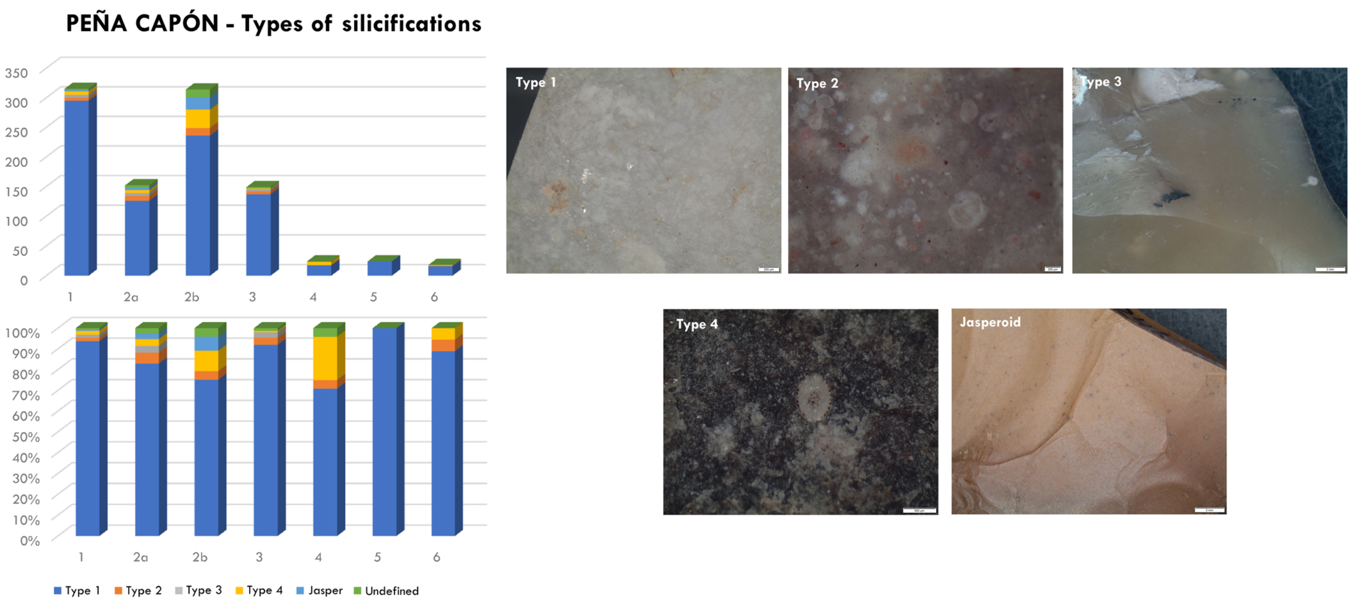

FIGURE 6 Graph with the averages of each chert type from Peña Capón distributed by levels and macroscopic detail of the five siliceous varieties.

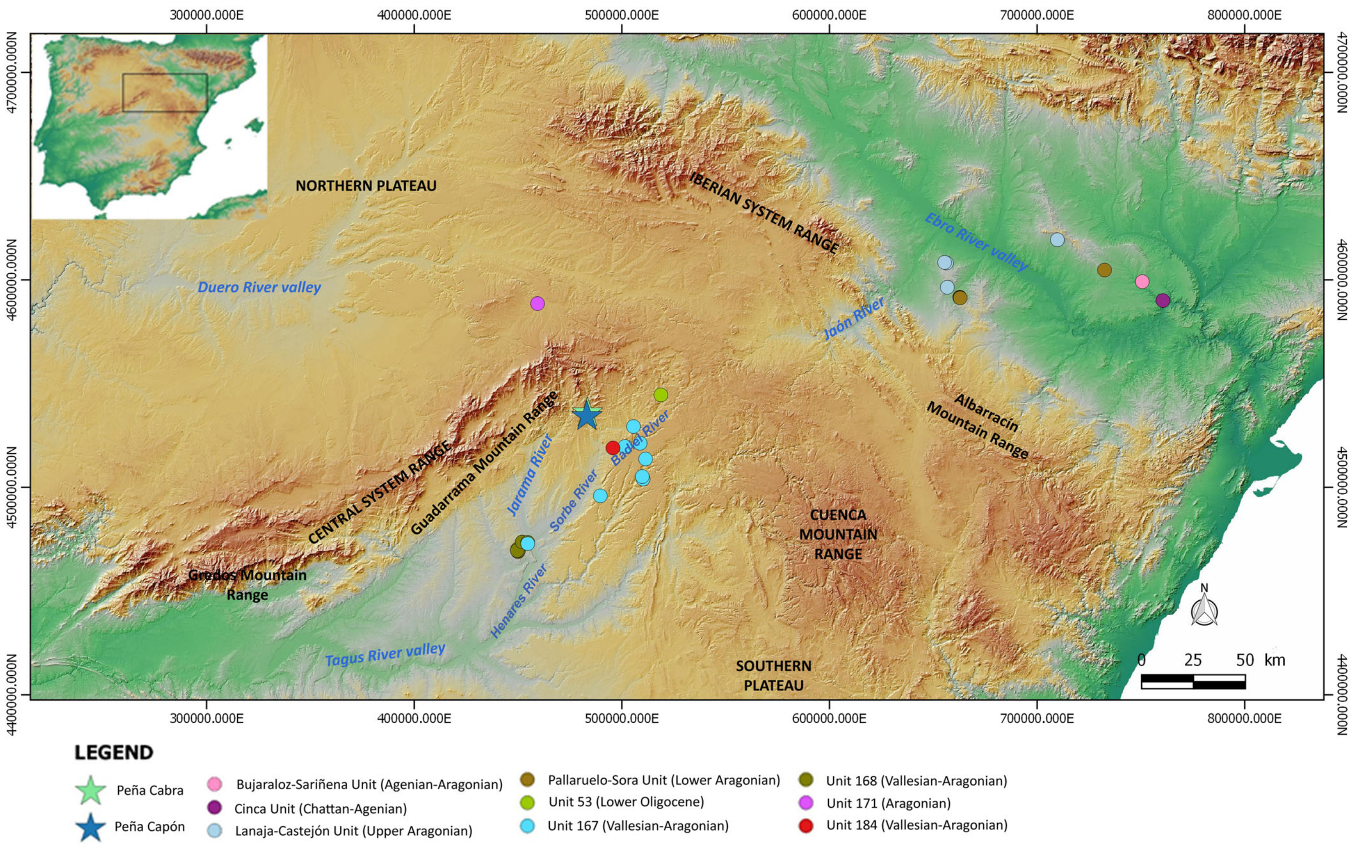

FIGURE 7 Location of the geological formations that, according to the macroscopic studies, could have been frequented by groups settled at Peña Cabra and Peña Capón sites.

predominant texture oscillates between mudstone to wackestone type depending on the sample.

4 | DISCUSSION

The geoarchaeological fieldworks aimed at locating chert outcrops, and the subsequent macroscopic and petrographic approach to characterise the recovered samples, have allowed us to present a wide variety of siliceous raw materials outcropping in the central regions of inland Iberia. This study, which builds on previous works by other researchers in the Madrid basin (M. E. Arribas & Bustillo, 1985; Bustillo, 1976, 1980; Parcerisas & Tarrino, 2008), contributes new data to the area connecting the Madrid basin with the Iberian System range.

Cherts outcropping in the Madrid basin were largely exploited during the prehistory. There are thus attested several Acheulian chert quarries in this area (Bárez del Cueto et al., 2016) and archaeological works at El Cañaveral sites (Coslada/Madrid, Madrid province) have demonstrated that human groups exploited these Miocene cherts since the Middle Palaeolithic. At these sites, which correspond to the geological outcrops of El Cañaveral—Área 3, CDP30 and Cañaveral—Parcela 32, the first stages of the lithic operative chain were documented near the primary chert deposit, including chert blank selection, core initial preparation and exploitation and residual activities. The presence of thermal alterations indicated the probable existence of combustion structures, maybe indicating the existence of open-air camps, where the chert acquisition was the main activity according to the recovered quarrying tools (Baena et al., 2011; Baena Ortiz Nieto-Márquez & Baena Preysler, 2017; Preysler et al., 2015). Besides, during the Holocene, the Casa Montero Neolithic mine is another example of the intensive exploitation of the Miocene cherts from the Madrid basin. At this site, up to three siliceous varieties (chert, opal and opaline chert) were exploited during the Neolithic. The archaeological works revealed that more than 3.800 extraction pits were conducted to obtain chert and opals outcropping among the Aragonian deposits (Bustillo & Pérez-Jiménez, 2005; Consuegra et al., 2018).

Our study focussed on the macroscopic and microscopic analysis of lithic samples from the Peña Cabra and Peña Capón rock shelters has yielded relevant information regarding the raw material acquisition strategies employed by Middle and Upper Palaeolithic groups settled in this region of inland Iberia. In Peña Cabra, four siliceous varieties have been identified, of which the evaporitic cherts (type 1) were the most frequently exploited. Although the macroscopic approach presents some limitations, it nevertheless offers the best opportunity to identify the geological formations potentially exploited by past human groups. In this respect, the evaporitic cherts from Peña Cabra are macroscopically similar to the evaporitic variety from Unit 167 (Vallesian-Aragonian cherts), outcropping in the upper Henares and Badiel Rivers valley, located very close to the archaeological sites, as well as to the cherts from Units 53 (Lower Oligocene cherts) and 184 (Vallesian-Aragonian cherts), also outcropping in this area from the upper Henares and Badiel River valleys (Figure 7). At this scale of analysis, we were unable to directly relate the evaporitic archaeological cherts from Peña Cabra to one specific geological formation. Therefore, it will be necessary to move forward on our research by adding the elemental chemical characterisation, to test whether it is possible to directly relate the archaeological cherts from Peña Cabra to a specific geological unit. In this regard, the geochemical analysis developed by Bustillo and colleagues on different siliceous layers outcropping in the Casa Montero site, suggests that differences between layers could be established based on the amount of rare elements (Bustillo & Pérez, 2016; Bustillo et al., 2012). Similarly, the petrographic and geochemical analysis of the Mousterian assemblages from the Navalmaíllo rock shelter (Pinilla del Valle, Madrid province) seems to reveal a correspondence between the evaporitic chert artefacts and the evaporitic chert sources outcropping in the Lozoya valley (Abrunhosa et al., 2020).

In Peña Capón we identified three macroscopic varieties of evaporitic chert (types 1–3). Cherts defined as type 1 are macroscopically similar to cherts outcropping in the upper Henares and Badiel Rivers valleys (evaporitic cherts from Unit 53, evaporitic variety from Unit 167 and evaporitic cherts from Unit 184). The evaporitic variety defined as type 2 presents similar macroscopic textures as cherts from unit 168, the outcrops of which are located in the middle Henares River valley, some 50 km to the south of Peña Capón. However, it is not possible to directly relate the third evaporitic variety (type 3) to any of the geological outcrops identified to date in this region of inland Iberia. These cherts, which are not very common in the archaeological record, may have been transported from other regions. In this regard, it is important to note that in several neighbouring regions there are evaporitic cherts that were largely exploited during the Upper Palaeolithic, such as the evaporitic cherts from the Middle Ebro Basin. These were sporadically used by the Magdalenians groups settled sites such as Arba de Biel (Biel, Zaragoza) or Arenal de Fonseca (Ladruñán, Teruel) (García-Simón, 2018).

Concerning the origin of the lacustrine cherts collected at Peña Cabra (type 2) and Peña Capón (type 4), we have determined that the samples from both sites show similar macroscopic features but do not fit with the lacustrine formations identified during the field surveys (lacustrine variety from Unit 167 and lacustrine cherts from Unit 195). In this regard, the archaeological cherts are similar to the various lacustrine formations outcropping in the Ebro River valley (Bujaraloz-Sariñena Unit, Cinca Unit, Lanaja-Castejón Unit and Pallaruelo-Sora Unit) (Sánchez de la Torre et al., 2019). These lacustrine cherts, commonly known as *Monegros* cherts, are widely exploited during the Upper Palaeolithic, with outstanding examples at the Pre-Pyrenean settlements of Arba de Biel (Biel, Zaragoza) (García-Simón, 2018), Fuente del Trucho (Sánchez de la Torre, Utrilla, Montes et al., 2020) or Chaves Cave (Sánchez de la Torre, Utrilla, Domingo et al., 2020). Our macroscopic analysis has enabled us to propose these formations as potential catchment sources for the hunter-gatherers settled at Peña Cabra and Peña Capón, but the application of further analytical approaches, such as the geochemical analysis, is necessary to discriminate between sources and establish a direct relationship between the archaeological cherts and a specific geological unit. Anyhow, given that these geological units from the Ebro valley are located more than 150 km away from the two sites under study, and if our hypothesis is confirmed, it would suggest the existence of contacts and or movements between the Ebro the Tagus valleys, perhaps following the course of the Jalón River, as previously suggested by other researchers (Utrilla et al., 2012).

At the current stage of our research, it is not possible to relate neither the jasper siliceous varieties found at Peña Cabra and Peña Capón, nor the two marine cherts recovered at Peña Cabra, to any of the studied geological units. These may have their origin in other geological units outcropping in this region of inland Iberia, which have not yet been surveyed, or they may indicate remote catchment areas located beyond the prospected area reported here.

5 | CONCLUSIONS

The two field surveys carried out in 2018 and 2020 have enabled the identification of eight geological units, five of which are placed in the vicinities of the Peña Cabra and Peña Capón sites. The Henares and Badiel Rivers valleys, tributaries of the Upper Tagus River basin, were intensively surveyed and chert outcrops from five different geological units were analysed. To the north of the Central System range, two further outcrops in two different geological units were also defined, and another unit with chert was identified in the foothills to the east of the archaeological sites, between the Iberian System and the Cuenca mountains.

Macroscopic and petrographic characterisation of the eight surveyed units has enabled identification of three main chert varieties (evaporitic, lacustrine and marine), some of which included limestones in the process of silicification (lacustrine variety from Unit 167, evaporitic chert from Unit 171 and evaporitic chert from Unit 195). Two chert units contained stratified marine cherts that were highly tectonized, and therefore had a very low knapping potential due to intensive cracking (Units 166 and 134). Thus, our macroscopic and petrographic study of the geological samples indicated that only four of the eight surveyed units contained cherts that could have been exploited by past human groups. However, their similar macroscopic and petrographic features prevented differentiation at these scales of analysis. Consequently, we performed geochemical analyses to determine whether it was possible to establish differences between outcrops within the same geological formation. Our results are not conclusive and at the moment, the analysed outcrops cannot clearly be differentiated. Thus, future geochemical studies incorporating all the studied outcrops will be necessary to determine whether it is possible to address a direct relationship between the evaporitic cherts found at the Peña Cabra and Peña Capón sites and a specific geological unit. In addition, it will also be necessary to conduct geochemical analyses of the lacustrine cherts in the archaeological record of these sites and compare the results with those for other chert sources outcropping in the Ebro Basin and other regions, to demonstrate potential contacts between hunter-gatherers settled along the Tagus and Ebro Rivers valleys, and perhaps other areas of Iberia, during the Middle and Upper Palaeolithic.

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