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Characterising the lithic raw materials from Fuente del Trucho (Asque-Colungo, Huesca). New data about Palaeolithic human mobility in NE Iberia

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Abstract

The Fuente del Trucho Cave (Asque-Colungo, Huesca, Spain) is located in the central Pre-Pyrenean range in NE Iberia, in the Arpán ravine, a tributary of the Vero River. The mouth of the cave is 22 m wide and it is oriented to the SE. The entrance gives access to a 24 m deep hall. Palaeolithic paintings were discovered in the cave in 1978. The Fuente del Trucho art comprises two sectors, the external with some engraved motifs and the internal featuring more than 100 painted motifs distributed in 21 panels. Archaeological works have been undertaken since 1979, identifying several human occupations from the Middle and Upper Palaeolithic.

This paper presents results obtained after the analysis of lithic raw materials. The analyses have been done using the classical archaeopetrological approach, which comprises textural, micropalaeontological and petrographical analyses, combined with the application of geochemical methods, using Energy-dispersive X-ray Fluorescence (ED-XRF) and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). The results show that chert and quartzites were the most commonly used rocks. Different types and origins of chert

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have been identified, demonstrating the existence of a wide mobility for lithic raw material procurement along all the Palaeolithic occupations.

Keywords

Chert characterization, Middle Palaeolithic, Upper Palaeolithic, geochemistry, Pyrenees

Introduction

Fuente del Trucho is a deep rockshelter located in the heart of the River Vero canyons, in the Guara Mountain Range, placed in the Central Pre-Pyrenean area (NE Spain) (**Figure 1**). It was discovered in the late seventies by the Museum of Huesca and the University of Zaragoza surveying team, headed by V. Baldellou, and to date it remains as the only figurative Paleolithic cave art site in the Ebro Depression (Utrilla et al., 2013; Utrilla and Bea, 2015). Recently, some of the crusts growing above the paintings have been dated by U/Th and indicate that horses and hand stencils were painted during Gravettian(Hoffmann et al., 2017).

The site has been excavated by two teams since its discovery. First works were carried out in the eighties by A. Mir (Mir and Salas, 2000). Since 2005, a team from the University of Zaragoza headed by P. Utrilla, L. Montes and M. Bea have continued the fieldworks with two different excavation areas (Utrilla et al., 2014b). The dusty sediments in most of the internal area did not preserve any sedimentological structure; material remains were abundant and could be typologically assigned to several periods of the Middle and Upper Palaeolithic, but they appeared considerably disturbed. Besides this, at the bottom of the survey, some less disturbed sections appeared, defined as probable undisturbed Mousterian levels (mi1 and mi2), offering scarce material assemblages (Montes et al., 2006).

The external zone can be divided in two areas: the closest to the engraved panel had been affected by Early Medieval domestic structures that we linked, after a charcoal dated from the hearth (1235±35 BP), to the *razzias* (raids) that Abd al-Rahman I inflicted in the late 8th century. The rest of the excavated area shows a stratigraphic sequence whose uppermost levels ("c" and "d") are severely affected by the Medieval pits and do not include many prehistoric remains. A bone from the upper part of level d was dated to 26,020±150 BP, which points to Gravettian, and another from the bottom seems to mark the transition between this unit and the level e in 31,880±220 BP. Level e, barely excavated and still lacking a precise chronology, could belong to Mousterian, after its poor set of lithic industry where quartzite flakes predominate (Montes et al., 2006; Utrilla et al., 2014a).

Future archaeological works will try to better characterize these levels and to link the hitherto unconnected excavation areas in order to obtain a comprehensive view of the prehistoric occupations.

The aim of this study is to characterise lithic raw materials recovered at Palaeolithic levels from the Fuente del Trucho cave as means of tracing the mobility patterns and territoriality of hunter-gatherer communities during the Palaeolithic in NE Iberia. To achieve these goals, the classic archaeopetrological approach using textural, micropalaeontological and petrographical descriptions has been applied. Moreover, geochemical techniques have been incorporated to carry out a complete characterisation of the lithic tools in greater depth.

Materials and methods

Archaeological materials: the studied set

A total of 4,036 archaeological lithic remains recovered in the internal and external excavation areas have been analysed. Most of the studied lithic remains were recovered in the mixed ensemble, with 3,169 remains. The remaining 867 are ascribed to the stratified levels from the external sector: breach (58), c (56), d (459) and e (48), as well as from mi1 (122) and mi2 (133) levels from the internal area. Despite most of the studied remains coming from the mixed disturbed set, a further detailed analysis correlating their tool types with chert varieties provides interesting information.

The entire set was macroscopically analysed to define the textural and micropalaeontological features. A basic technological and typological analysis was also done. As regards technological aspects, sample dimensions and weight were measured, as well as the type of support with the aim of specifying information concerning the *Chaîne opératoire lithique*. Typological analyses were done following both the Analytical typology developed by Laplace (Laplace, 1974) and the Sonneville-Bordes – Perrot list (Sonneville-Bordes and Perrot, 1954).

Once the first lithological groups defined during macroscopic observations, 12 samples were selected for petrographic studies in order to describe each group. Moreover, 21 samples recovered in the mixed ensemble were analysed by ED-XRF and 6 specimens also found in the mixed set by LA-ICP-MS. Information regarding the methodology of each analytical technique is presented below.

Geological materials: the compared database

With the aim of comparing results obtained after the analysis of archaeological remains, geological formations with cherts outcropping in NE Iberia and specifically in the Pyrenean region and the Ebro Depression have been surveyed, sampled and studied during recent years (Sánchez De la Torre et al., 2019a; Sánchez de la Torre et al., 2019b; Sánchez de la Torre et al., 2017b; Sánchez de la Torre and Mangado, 2016). In this study, the archaeological lithological groups from Fuente del Trucho were compared with eleven geological formations possessing similar characteristics and outcropping in the Ebro Depression and the Pyrenean mountain range, being in sum almost twenty different outcrops selected for study. Each of the selected outcrops had been surveyed and samples were collected with the aim of obtaining a broad representation of the internal variability of the outcrop. Samples selected for petrographic studies were prepared in thin sections, and samples for geochemical analyses were prepared in squares of 5 x 5 mm without cortex surfaces in order to improve analysis time and avoid surface alterations. In total, 370 geological samples were analysed by ED-XRF and 89 by LA-ICP-MS (**Table 1**).

Methods: textural, micropalaeontological and petrographic analyses

A textural and micropalaeontological examination of the archaeological set was done using a stereoscopic microscope, an Ultralyt M-51000 with internal light source and an Olympus SZ61 model (6.7 to 45 x). Snapshots were taken with a coupled Olympus SC30 camera. A petrographic and micropalaeontological characterization of the defined types of chert was also performed by analysing them in thin sections that were analysed using a petrographic Olympus BX41 microscope.

Methods: geochemical analyses

ED-XRF was employed to analyse major and minor elements. The analyses were done at the IRAMAT laboratory (Pessac, France). Nine element concentrations were quantified (Na, Mg, Al, Si, P, K, Ca, Ti, Fe) with an X-ray fluorescence spectrometer SEIKO SEA 6000 VX using fundamental parameters corrected by the granodiorite GSP2 from the US Geological Survey international standard. A 3 x 3 mm collimator was used, and analysis time was set to 400 s for each measurement condition. To check machine calibration and accuracy, the JCh-1 chert standard from the Geological Survey of Japan was employed (Sánchez de la Torre et al., 2017b).

To analyse trace elements, LA-ICP-MS was carried out at the Ernest Babelon laboratory, IRAMAT (Orleans, France). Elements were quantified using a Thermo Fisher Scientific Element XR mass spectrometer coupled with a Resonetics RESOlution M50e ablation device. The ablation device is an excimer laser (ArF, 193 nm), which was operated at 7-8 mj and 20 Hz. A dual gas system with helium (0.65 l/min) released at the base of the chamber, and argon at the head of the chamber (1.1 l/min), carried the ablated material to the plasma torch. Ablation time was set to 33 s: 10 s preablation to let the ablated material reach the spectrometer and 23 s to scan from lithium to uranium. Laser spot size was set to 100 µm, and line mode acquisition was chosen to enhance sensitivity. Fresh fractures were analysed on geological samples to reduce potential contamination. Calibration was performed using standard reference glass NIST610 which was run periodically to correct for drift. NIST610 was used to calculate the response coefficient (k) of each element (Gratuze, 1999, 2014), and the measured values of each element were normalised against 28Si, the internal standard, to produce a final percentage. Glass Standard NIST612 was analysed independently of calibration to provide comparative data. A total of 29 elements were quantified (Li, Be, B, Mg, Al, Si, Ca, Ti, V, Cr, Fe, Ga, As, Rb, Sr, Y, Zr, Nb, Cs, Ba, La, Ce, Pr, Nd, Sm, W, Bi, Th, U).

Results

Lithological groups defined by macroscopic and petrographic characterizations

Two lithologies were predominant in the set: chert and quartzites, having also recognised scarce lydites, quartz and silicified limestones (**Figure 2-A**). The stratified levels provide a scarce diagnostic value, being some of them poor in samples (breach, c and e levels) and these from the internal sector with a partially questionable integrity. Under these premises, and leaving aside the mixed set, in the internal sector chert was predominant in both Mousterian mi1 and mi2 levels, with averages rounding the 50%. In the external sector the difference between lithologies seems clearer and mostly related to cultural changes. Thus, in the Upper Palaeolithic breach and c levels, chert rises to 91% and 84% respectively, whereas in level e (Middle Palaeolithic) it decreases down to 19%. In level d, considered as Gravettian following the obtained radiocarbon date, quartzites prevail over chert (55% vs 39%). In this sense, changes along levels and phases can be observed, with the increase of the exploitation of chert over time. If so, the predominance of chert in the mixed ensemble (60% vs 32% of quartzites) could reflect large disturbances into the Upper Palaeolithic levels.

The macroscopic observation allowed the identification of up to six different types of chert (**Figure 2-B**), besides an indeterminate group composed of 164 samples without specific features or too altered to be analysed. We define in the following lines the features of each chert type as well as the geological formations containing chert that macroscopically and petrographically fit with the archaeological samples (**Figure 3**).

Type 1 is constituted by 507 samples, representing 22% of the total set (the 19% of the stratified cherts). Macroscopically, this chert possesses a texture with metal oxide, micritic residues, grains of detrital quartz and probably organic matter inclusions. *Charophyte algae* and gastropods constitute the main micropalaeontological content. At the petrographic level, microquartz mosaic fabric constitutes the main texture, with cementations of length-fast chalcedony and macroquartz. These cherts originated in a lacustrine environment and macroscopically converge with the so-called Monegros cherts (García-Simón, 2018). Nevertheless, seven geological formations outcropping not only in the Ebro Depression, but also in the Pre-Pyrenean region possess identical features at the macroscopic and petrographic scale (Sánchez De la Torre et al., 2019a).

- The **Tremp formation** (Maastrichtian) possesses a level of laminated micritic limestones with *Charophyte algae* and gastropod moulds filled with sparite (IGME, e.p.). This formation, that also contains a nodular chert level, outcrops in the Carrodilla mountain range, a Pre-Pyrenean foothill located between the Cinca River Basin to the west and the Noguera Ribagorzana River to the east. The outcrops were identified near the villages of Estadilla (Mentirosa) and Zurita (Huesca, Spain).
- The **Castelltallat formation** (Rupelian) largely outcrops in Serra Llarga (IGME, 1998), a mountain chain located between the towns of Castelló de Farfanya and Alfarràs (Lleida, Spain) (Anadón et al., 1989; Mangado, 2005). The presence of chert nodules from this formation has also been noticed near the village of Peraltilla (Huesca, Spain), 60 kilometres to the west of Serra Llarga and close to the Fuente del Trucho cave (Sáez, 1987).
- The **Tartareu-Alberola** cherts (Rupelian) appear within the lacustrine stratified limestones outcropping near the village of Alberola (Lleida, Spain), in the San Miquel

mountain range, a Pre-Pyrenean mountain chain located to the north of Serra Llarga (IGC, 2008).

- The **Torrente de Cinca – Alcolea de Cinca** unit (Chattian-Agenian) appears as detrital facies in the northern and southern margins of the Ebro Depression, having identified an important complex of chert outcrops in Valcuerna (Huesca, Spain) (García-Simón, 2018).
- In the **Bujaraloz-Sariñena** unit (Agenian-Aragonian), chert outcrop within the stratified limestones and marls intercalated with clay near the towns of Peñalba and Candasnos (Huesca, Spain).
- The **Sierra de Lanaja – Montes de Castejón** unit (Upper Aragonian) possess chert nodules embedded in the silty limestones that form the San Caprasio hill, next the town of Farlete (La Torraza) (Zaragoza, Spain) (García-Simón, 2018), at the north of the Ebro River, as well as in the hills next to the towns of Muel (Campo de las Horgas) (Zaragoza, Spain) and La Muela (Zaragoza, Spain), being these outcrops located at the south of the Ebro River. In La Muela outcrops, evidence of knapping in modern times have been found (Barandiarán, 1974; Tarriño et al., 2016).
- The **Sierra de Pallaruelo – Monte de la Sora** unit (Lower Aragonian) possess several sandstone and limestone levels where some chert nodules were identified. They appear in two areas from the Middle Ebro Depression: near the town of La Almolda (Santa Quiteria), at the north of the Ebro River, and in the hills of San Borombón mountain chain, near the towns of Muel and Mezalocha (Zaragoza, Spain) (García-Simón, 2018), at the south of the Ebro River.

Type 2 is represented by 1,031 artefacts, constituting the 44% of the complete studied set (41% in the stratified levels). This raw material is characterised by the absence of bioclastic content, as these cherts originated in a hypersaline sedimentation environment. The texture is quite smooth, with only a few inclusions of metal oxides and lenticular gypsum pseudomorphs being observed. Microscopically, a microquartz fabric is the main texture, but cementations of length-fast and length-slow chalcedony and macroquartz are also identified. Metal oxides and evaporitic evidences are abundant. Parallels can be directly drawn between this raw material and cherts from the Garumnian Tremp formation, outcropping in the contact area between the Ebro Depression and the Pre-Pyrenees (Sánchez de la Torre, 2015).

- The **Tremp formation** (Garumnian) is composed of a serial of stratified limestones that also contain some nodular cherts (IGME, e.p.). Several chert outcrops have been identified in the Carrodilla (Alins) and Montsec mountain ranges (Fontllonga, Peralba and VSSM).

Type 3 is represented by 17 samples and constitutes less than the 1% of the sample, being just identified in the mixed set. This chert is macroscopically characterised by a texture composed of abundant metal oxides and detrital quartz crystals. The main micropalaeontological content is composed of sponge spicules. Under the petrographic microscope, a microquartz mosaic fabric is revealed as the main texture, with the occasional appearance of length-fast chalcedony. This is a chert type originated in a marine environment and which could be related with three different chert outcrops from the northern slope of the Central Pyrenees (Montgaillard, Buala and Montsaunès) (Sánchez de la Torre et al., 2017a; Sánchez de la Torre et al., 2019b).

- The **Montgaillard flysch cherts** originate in the flysch limestones (Turonian-Santonian) outcropping in primary position near Montgaillard town (Hautes-Pyrénées, France) (Barragué et al., 2001).
- The Montsaunès-Buala cherts are inserted in the **Nankin formation** limestones (Middle Maastrichtian) outcropping in the ancient quarry of Montsaunès (Haute-Garonne, France) (Séronie-Vivien et al., 2006) and the ancient quarry of Buala, near the town of Montgaillard (Hautes-Pyrenées, France) (Sánchez de la Torre et al., 2019b).

Type 4 is composed of 243 artefacts and constitutes the 10% of the sample, going up to the 16% in the stratified levels. Macroscopically is constituted by inclusions of metal oxides, abundant detrital quartz crystals, calcite or dolomite rhombohedral crystals and probably organic matter as impurities. Sponge spicules and small foraminifera (globigerinids) comprise the micropalaeontological content. Under the petrographic microscope, a microquartz mosaic fabric is observed as the main texture, being the only silica texture identified. Type 4 can be directly related to cherts from the Agua-Salenz formation, outcropping in the southern slopes of the Central Pyrenees.

- The **Agua-Salenz formation** (Conacian) is constituted by limestones with pithonelles, sponge spicules and nodular cherts, outcropping in the Lierp Valley, at the south of the Turbón Massif, in the municipality of Padarniu (Huesca, Spain), where remains of ancient workshops where detected (Sánchez de la Torre and Mangado, 2016).

Type 5 is represented by 10 samples and represents only the 0,4% of the entire set, going up to the 1,2% in the internal Mousterian levels, jointly considered. Macroscopically this chert is constituted by scarce metal oxides, the texture being almost always of mudstone type. The micropalaeontologcical content is composed of some *Dasycladacae algae* and other bioclastic remains, not yet well identified. For the moment we cannot identify a specific geological formation that fits macroscopically with type 5, as we have not yet found parallels with the same features.

Type 6 is composed of 370 samples, reaching the 16% of the entire set and just the 11% if only stratified levels are considered. Macroscopically, it is composed of metal oxides and detrital quartz crystals. Cortical surfaces are predominant. The micropalaeontological content is composed of sponge spicules and the abundance of macroforaminifera, having identified *Discocyclina, Nummulites, Alveolina* and *Assilina*. Under the petrographic microscope, a microquartz mosaic fabric is the sole silica texture. We have not yet identified chert outcrops with the same characteristics as the observed within this chert type. Regarding the micropalaeontological content, there is a limestone formation containing the same association of macroforaminifera outcropping near Fuente del Trucho site. It is a limestone formation from the Lutecian possessing an association of *Discocyclina*, *Alveolina*, *Assilina* and *Nummulites*. It largely outcrops in the Guara Mountain Range, being also present near the Fuente del Trucho site, in the Arpán and Trucho ravines, a few hundred meters at the north of the site. Taking into account the high average of cortical surfaces, a local origin could be proposed. At the moment of composition of this paper, no chert outcrop have been located, but fieldwork in the area continues.

Distribution of the chert types by archaeological levels

Differences are observed in the distribution of each type between levels, although we must consider the poverty of the stratified levels. Types 1, 2 and 4 are the best represented in almost all levels, being the exception level e, whose very poor record (9 chert remains) practically nullifies its data. Type 1 predominates in breach level and equals type 2 at c level, whereas type 2 was the most employed chert in mi1 and mi2 Mousterian levels, as well as in the so-called Gravettian level d, followed in these levels by type 4. The rare type 3 has only been detected in the mixed set and type 5, even scarcer, only appeared in the archaeological levels from the internal area of excavation (mi1 and mi2) and the mixed set from this sector. Finally, type 6, the probable local chert source, appears in all the sequence.

Technological and typological data

The technological analysis was done with the aim of identifying possible different strategies depending on the lithology, the chert type or the archaeological level. Some differences are observed between levels mostly concerning the appearance of flake and blade products (**Figure 2-C**). Thus, it seems that quartzites were mostly used for the production of flake products for almost all levels (except c and breach), while the greatest evidence of blade products in this lithology appears in the mixed ensemble. It has to be highlighted that these quartzite blades are considered as blade products just due to typometric aspects, but they cannot be considered proper blades from a technological point of view.

Concerning the technological aspects of just chert supports, flake products are predominant in the entire set for all types of chert, being the exception the rare type 3 (**Figure 2-D**). It seems that during the Upper Palaeolithic type 1 was preferred, followed by type 2, whereas during the Middle Palaeolithic type 2 was firstly selected, followed by types 4 and 6. In brief, it seems clear that the mixed ensemble and levels breach and c present similar technological features, whereas levels d, e, mi1 and mi2 possess similar technological characteristics, mostly based on the production of flake products. The relation between the mixed set and levels breach and c could be due to the supposed greater contribution of disturbed Upper Palaeolithic levels in the mixed ensemble, whereas the similar behaviour of level d (supposedly Gravettian) and the Mousterian levels (e, mi1 and mi2) could be explained either by the archaic character of this Upper Palaeolithic phase or by the presence in level d of Mousterian materials from level e due to an ancient mixture not seen during the excavation.

The typological analysis of the retouched pieces has given some interesting results (**Figure 2-E**). The retouched pieces are around the 15% of the number of samples analysed in almost all ensembles. Important differences are observed in the distribution of the main lithologies between levels. Quartzites were almost exclusively used for the manufacture of simple retouch pieces, whereas chert was used for the elaboration of simple but also abrupt and other retouched objects. Regarding the distribution by archaeological levels, the simple retouch is predominant, being the exception levels breach and c, where abrupt retouch predominates. These data clearly indicate that the breach and c levels are quite different from levels d, e, mi1 and mi2, which present a similar behaviour. In the mixed set were detected other typological groups as burins and foliaceous pieces, indicating the presence within this set of different human occupations with diverse typological behaviours. Regarding the preferred chert types for the production of retouched pieces, some slight differences were observed between levels. In that way, in levels d, e, mi1 and mi2, types 2 and 4 were preferred, despite having also documented finished tools made on types 1, 5 and 6. Thus, in levels breach and c, type 1 was the preferred for the manufacture of retouched pieces, followed by types 2 and 4.

Taking into account that a high number of samples was recovered in the mixed sediments, a specific study was done with samples from this set. The aim was to identify specific typological markers exclusives from a chronocultural period for determining the used chert type. Despite being a preliminary approach, some interesting data can be distinguished. Regarding the presence of type 3 cherts, which are exclusives from the mixed ensemble, the retouched pieces made on this chert are basically endscrapers, burins and backed bladelets, that typologically could be ascribed to Gravettian or Magdalenian occupations. Some carenated and nosed endscrapers typically associated to the Aurignacian were also recognised in the mixed set, being made on type 2 cherts. In a similar way, some foliaceous tools related to a Solutrean occupation of the cave were documented, being made on the same type of chert. However, the Mediterranean-type abrupt-retouched shouldered points also linked to the Solutrean period (Fullola et al., 2019) were mostly made on type 1.

Geochemical analyses: ED-XRF and LA-ICP-MS results

Geochemical analyses were undertaken to determine the chemical composition of some few archaeological samples for try to establish a first relationship with specific geological outcrops. Samples from types 1, 3 and 4 recovered at the mixed set were selected as being the most suitable chert types for geochemical analyses. Cherts from types 2, 5 and 6 were discarded for the geochemical analysis for possessing scarce inclusions and thus being too rich in SiO_2 (type 2) or for not having geological samples to be compared with (types 5 and 6).

ED-XRF analyses were undertaken to quantify major and minor elements in 12 samples from types 1. While nine oxides were measured, data relating to Na_2O and P_2O_5 was limited as their values were almost always below the equipment's detection limits. LA-ICP-MS analyses were done in order to identify and quantify trace elements. LA-ICP-MS was used to quantify the chemical composition of cherts from types 3 and 4, having analysed three samples of each chert type (see Supplementary Data).

Type 1, the lacustrine cherts, possess similar macroscopic and petrographic features to cherts from seven geological formations: four outcropping in the Ebro Depression (Bujaraloz-Sariñena, Cinca, Lanaja-Castejón and Pallaruelo-Sora units) and three in the contact area between the Ebro Depression and the Pre-Pyrenees (Castelltallat, Tremp and Tartareu-Alberola units). In this case, ED-XRF data has given some valuable information to link archaeological and geological samples. With the data obtained, discriminant analysis (DA) was run to see if quantified distinctions were visible at the major and minor elemental levels using XLSTAT software (Addinsoft, 2017). To calculate DA, three values were preferred: K_2O, Fe_2O_3 and Al_2O_3, as they allowed better distinguishing between the more than 300 analysed samples (see Supplementary Raw Data). The DA plot of the three selected elements for all the archaeological and geological samples shows some differences between formations (**Figure 4-top**). 89.46% of the total variance – F1 (66.59%) and F2 (22.88%) is represented. To facilitate the interpretation, all the archaeological samples, calculated as individuals, and just the ellipses of each geological formation are symbolised. It can quickly be observed an overlapping area between some of the geological formations, mostly affecting to Tremp, Bujaraloz-Sariñena, Castelltallat and Pallaruelo-Sora dispersions. The archaeological samples appear slightly concentrated in the main dispersion of Lanaja-Castejón group, but some of them could also be linked to Cinca group. Moreover, as the dispersion area of Tartareu-Alberola group is so large regarding the high variability intragroup, the archaeological samples could also be associated to this geological group, whose ellipse occupies a large part of the plot.

Following a multi-statistical analysis, the Mahalanobis distance between the archaeological samples from Fuente del Trucho and each geological formation was calculated (**Table 2**) based on the values obtained for Al_2O_3, CaO, Fe_2O_3, K_2O and SiO_2. For most of the archaeological samples, the shortest distances are obtained with the Lanaja-Castejón Unit. Nevertheless, in some samples, the distances are shorter with the Tartareu-Alberola formations (in three samples) and the Cinca Unit (in one sample). So, despite being Lanaja-Castejón closer to the main archaeological studied set, other sources cannot be discarded.

Finally, to increase the statistical analysis, a scatterplot of K_2O, Fe_2O_3 and Al_2O_3 values was calculated (**Figure 4-bottom**). In this case, only the geological outcrops from the Lanaja-Castejón Unit (La Muela 1, La Muela 2 and Campo de las Horgas) fit with the main dispersion of most of the archaeological group. Moreover, the geological formations of Tartareu-Alberola, Tremp ambd Castelltallat, seem to be far from the archaeological samples' dispersion. However, the Bujaraloz-Sariñena Unit, the Pallaruelo-Sora Unit as well as the Cinca Unit cannot be directly discarded as potentially used, as they are located not too far from some of the studied archaeological samples. In that way, it seems that some of the analysed cherts macroscopically classified as type 1 could had their origin in the Lanaja-Castejón Unit, located in the Middle Ebro Depression. Nevertheless, we cannot discard the possibility that other formations could also had been frequented.

Three samples macroscopically defined as **Type 3** cherts were analysed to determine their geological origin. Three chert sources outcropping in the northern slope of the Central Pyrenees possess similar macroscopic and petrographic features. These are the Campanian-Maastrichtian flysch cherts from Buala, the Maastrichtian cherts from the Nankin Formation (Montsaunès) and the Turonian cherts from Montgaillard. ED-XRF analyses were first carried out, but no discriminatory results were established between the sources in terms of major and minor components. For this reason, LA-ICP-MS was run to identify and quantify trace elements. The results showed some trace elements could be discriminated to distinguish between sources. In the scatterplot for Ln Ti/Sr vs Ln Th/Sr, the three chert sources can be distinguished, the archaeological samples being placed in the main dispersion area of the Montgaillard samples (**Figure 5-top**).

Three cherts classified as **Type 4** were also analysed geochemically. Despite being macroscopically and petrographically associated with one Pyrenean formation, the Agua-Salenz formation, geochemical analyses were undertaken with the aim of confirming or rejecting these macroscopic and microscopic associations. While ED-XRF did not give discriminatory results for major and minor components, LA-ICP-MS analyses showed some interesting associations regarding specific trace elements. In the scatterplot for Ln Th/Sr vs Ln Ti/Sr, the four analysed archaeological samples originally defined as type 4 cherts fit with the main dispersion of the geological outcrop studied: the Padarniu outcrop, from the Agua-Salenz formation (**Figure 5-bottom**). The relation between the type 4 cherts and the geological cherts from the Agua-Salenz formation has thus been geochemically demonstrated.

Discussion

The complete archaeopetrological analysis of the lithic raw materials recovered at the Fuente del Trucho cave provided some data regarding acquisition strategies. First, clear differences were established between the so-called Upper and Middle Palaeolithic levels regarding the lithology used, providing further proof to identify the type of community associated with the different stratigraphic levels. In this sense, levels e, mi1 and mi2, probably ascribed to Middle Palaeolithic human occupations (with all the cautions expressed above), possessed a lithic industry where quartzites play an important role, whereas in the Upper Palaeolithic levels breach and c, cherts were the preferred rock type for the production of lithic tools. The supposed Gravettian level d breaks the trend, as quartzites clearly prevail over cherts. Moreover, the technological and typological analyses also support this differentiation between levels in terms of Middle and Upper Palaeolithic human occupations. Thus, for the levels defined as Middle Palaeolithic (e, mi1 and mi2), flake production is predominant and almost exclusive, both for quartzites and for chert remains. Furthermore, simple retouch tools are the sole retouched type in these units, done in quartzite and chert. Regarding the most exploited chert types, it seems that during the Middle Palaeolithic types 2 and 4 cherts were preferred, being type 4 the most selected chert type for the manufacture of retouched pieces, as typical Mousterian scrapers.

Leaving aside level d, whose data differ from the rest, for the clearly considered Upper Palaeolithic levels (breach and c levels and likely some of the materials recovered in the mixed set), chert was the most exploited rock, being clearly preferred to quartzites. Regarding chert remains, besides flake production, blade production is also documented, with some differences observed between chert types. Thus, it seems that types 2 and mostly type 1 were preferred, followed by types 6 and 4. The typological analysis specifically regarding chert tools showed that all the retouched types are almost represented in the Upper Palaeolithic units, although in low averages, identifying simple and abrupt retouches in all of them, as well as burins in level d and *écaillés* in level c. In the mixed set, besides the other groups, foliaceous tools were also recognised. A detailed analysis of the mixed ensemble was done concerning the so-called typological tracers, these lithic tools that by its appearance can be directly associated to a specific chronocultural period: some specific tracers from the Aurignacian, Solutrean and Magdalenian periods were recognised. Thus, we tried to directly determine the chert type of these specific tools with the aim to improve the data obtained. As a result, the so-called Aurignacian endscrapers were mostly made on type 2 cherts, as well as some flat-retouched tools from the Solutrean. However, the abrupt-retouched shouldered points also linked to the Solutrean period were mostly made on type 1 cherts. The association between specific tracers and their type of chert is thus limited, as there exist a large amount of retouched tools that persist during several Upper Palaeolithic periods with similar features (*e.g.* burins, cores, some endscrapers), being so impossible to directly relate some of these tools to a specific chronocultural period.

As regards the origins of the exploited chert types, the application of geochemical methods to complete the analysis of the lithic raw materials has given valuable information for identifying the formations and the possible exploited outcrops. Using ED-XRF, it has been possible to place several geological formations as suitable for the provisioning of the lacustrine archaeological cherts. These **type 1** cherts could fit with the main dispersion of some outcrops from the Lanaja-Castejón unit (La Muela 1, La Muela 2 and Campo de las Horgas), these outcrops being located in the Middle Ebro Depression, surprisingly on the other bank of the river, around 100 km to the south-west from the Fuente del Trucho cave. Despite being the Lanaja-Castejón formation also present in areas closest to the site, any chert outcrop has been recognised until now, being the closest outcrop located from this type La Torraza, which does not fit with type 1 cherts regarding the ED-XRF results. Besides, in the outcrops that better fit with the main dispersion of the type 1 cherts (La Muela 1 and La Muela 2) were also recognised abundant knapping remains. The exploitation of these outcrops during the XIX and XX century for the manufacture of gunflints has been documented, but some remains of probable prehistoric knapping have also been identified (Picazo et al., 2018; Sánchez De la Torre et al., 2019a; Tarriño et al., 2016).

The use of LA-ICP-MS to quantify the trace elements present in types 3 and 4 marine cherts has allowed the identification of the specific outcrops probably frequented by past human groups. Thus, the origin of **type 3** cherts has been geochemically demonstrated to be in the northern slopes of the Central Pyrenees, in particular the Montgaillard flysch cherts. This chert, which appears only in the mixed ensemble and probably associated to a Gravettian or Magdalenian occupation regarding the typological features of the retouched tools, confirms the existence of a large territory frequented by past societies. We are not able to establish whether these human groups provisioned themselves directly from this source or whether indirect provisioning strategies were followed. In any case, what is clear is that the territory of exploitation of some Upper Palaeolithic groups was larger than previously supposed. The location of the Gargas cave, some of whose painted motifs (namely, short-fingered hand stencils) present remarkable similarities to the ones found at Fuente del Trucho, next to the Montgaillard chert outcrops, reinforces the idea of a trans-Pyrenean territory that was frequented and exploited by those prehistoric groups. Furthermore, the origin of the **type 4** marine chert has also been geochemically confirmed by LA-ICP-MS. This chert type is directly linked with the Agua-Salenz formation cherts, specifically with the outcrops located at the south of the Turbón Massif. These outcrops are located at almost 50 km to the north-east of the archaeological site. This chert type, which was exploited during both the Middle and Upper Palaeolithic occupations, but specially during Mousterian times, is another indicator of the exploitation of the Pyrenean mountain range.

The results obtained after the archaeopetrological study of lithic raw materials from the Fuente del Trucho cave can be compared with those obtained by the same analytical conditions for the Upper Palaeolithic collections from the Cova Gran (Roy-Sunyer et al., 2013), Chaves Cave (Sánchez de la Torre et al., in press), Cova del Parco (Sánchez de la Torre et al., 2017a), the Forcas I rockshelter (Sánchez de la Torre et al., 2017a) and the Montlleó open-air site (Sánchez de la Torre et al., 2019c) and the Middle Palaeolithic collections from Roca dels Bous and Cova Gran (Roy-Sunyer, 2016). *Grosso modo*, regarding the Middle Palaeolithic sets, it seems clear that regional procurement strategies were predominant for Mousterian groups, having exploited the closest chert sources (mostly evaporitic cherts in Roca dels Bous and Cova Gran). Considering the Upper Palaeolithic levels, it can be highlighted that the general parameters are repeated for almost all the sites, specifically for the Magdalenian levels of Chaves, Forcas I and Parco. Lacustrine, evaporitic and marine cherts were also identified at these sites, being the same as those defined in this study as types 3 and 4. Their origin has been partially established and for types 2, 3 and 4 it seems that the same geological formations were exploited. Evidently the averages vary considerably and cannot be compared in detail as we are probably dealing with different chronocultural moments from the Upper Palaeolithic. Nevertheless, the presence of the main chert types (1, 2, 3 and 4) in the other studied sets from NE Iberia leads us to believe that the acquisition strategies for lithic raw materials were similar.

Conclusion

A complete archaeopetrological study of the Palaeolithic lithic remains recovered at the Fuente del Trucho cave since 2005 has been presented. The aim of this study was to define the different lithologies exploited and to specifically characterise chert remains to better determine the human mobility and territoriality of past prehistoric groups.

The study was first based on the classic archaeopetrological approach and then completed by geochemical analyses which allowed a better definition of the archaeological samples and their connection with specific chert outcrops. ED-XRF has given some data to relate lacustrine archaeological cherts with specific formations. Nevertheless, overlapping was observed within the discriminant analysis. LA-ICP-MS has proven to be indispensable for the establishment of differences between marine cherts, so it will be considered in the future for better defining the origin of lacustrine cherts.

Although the Fuente del Trucho cave is a difficult site for defining the different Palaeolithic human occupations due to the existence of disturbed areas, the archaeopetrological analysis of lithic remains has been invaluable for better identifying the territoriality of the prehistoric populations that inhabited the site. Moreover, combining typological and archaeopetrological analyses from samples recovered at the mixed set interesting data was obtained. Forthcoming research for determining the origin of types 5 and 6 cherts and the incorporation of new archaeological sets to be studied will increase our knowledge about Palaeolithic communities from NE Iberia and their lithic raw material procurement strategies.

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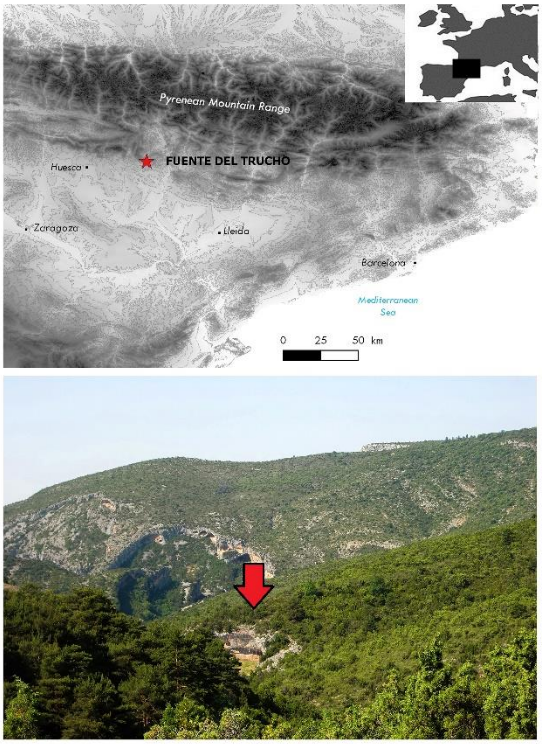
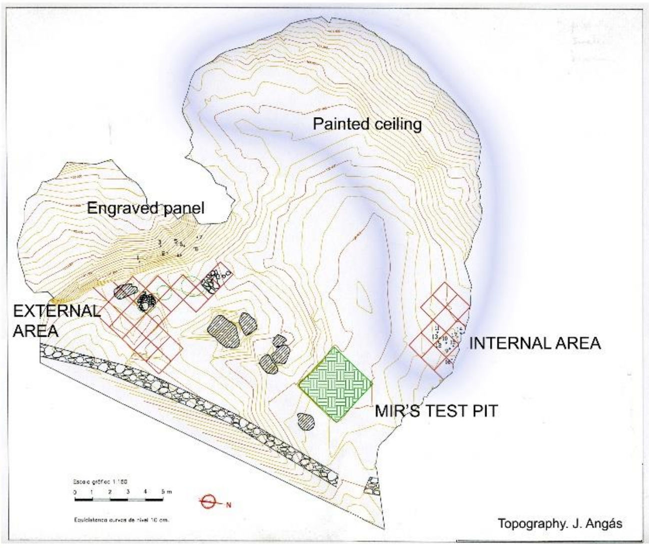




Reference	Material	Level	Date BP	Date cal BP
GrA-29918	Charcoal	*Modern* hearth	1235±35	1265-1069
GrA-29915	Bone	Mixed	20800±100	25414-24640
Beta-392868	Bone	d	26020±150	30735-29778
Beta-365760	Bone	d/e	31880±220	36266-35261

Figure 1 – Location of Fuente del Trucho Cave in NE Iberia, main view of the entrance,topography of the cavity and dates obtained by C14 AMS method.

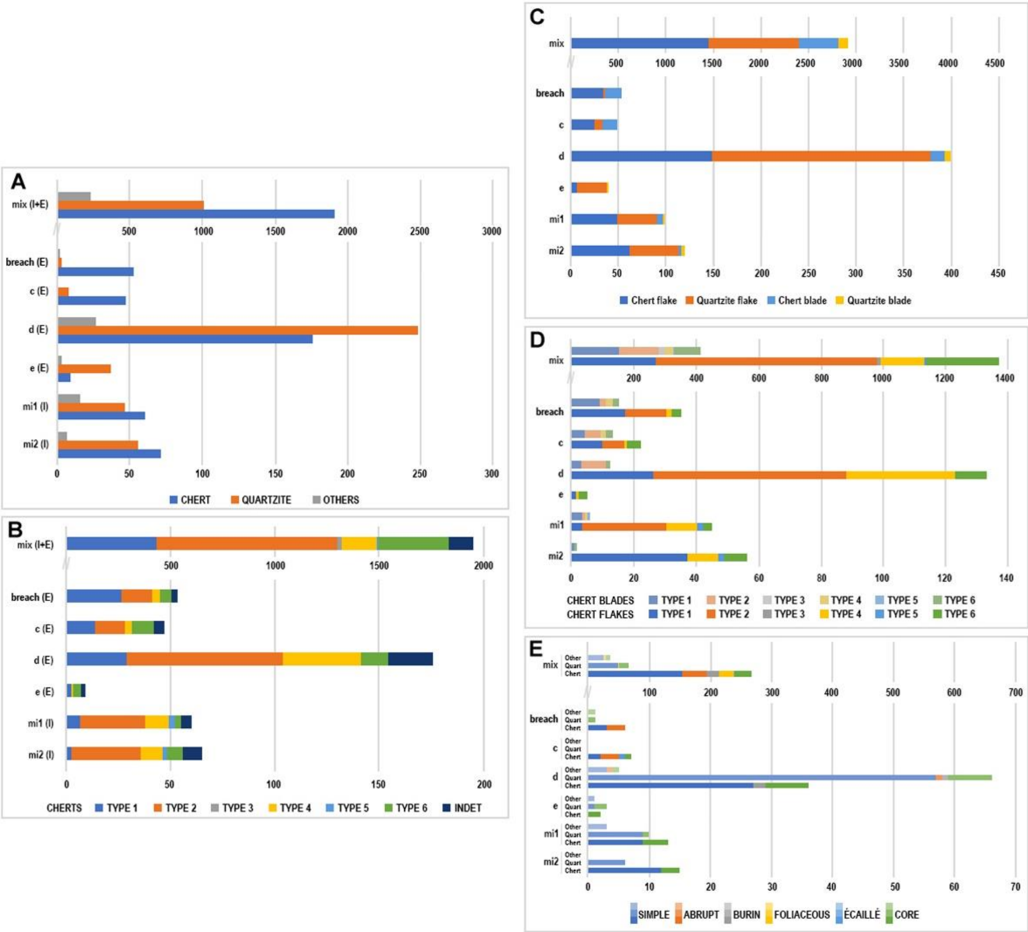


Figure 2 – Distribution by levels of the main lithologies (A) and the different chert types (B). Distribution by levels of flake and blade products by lithologies (C) and chert types (D) and typological distribution (E).

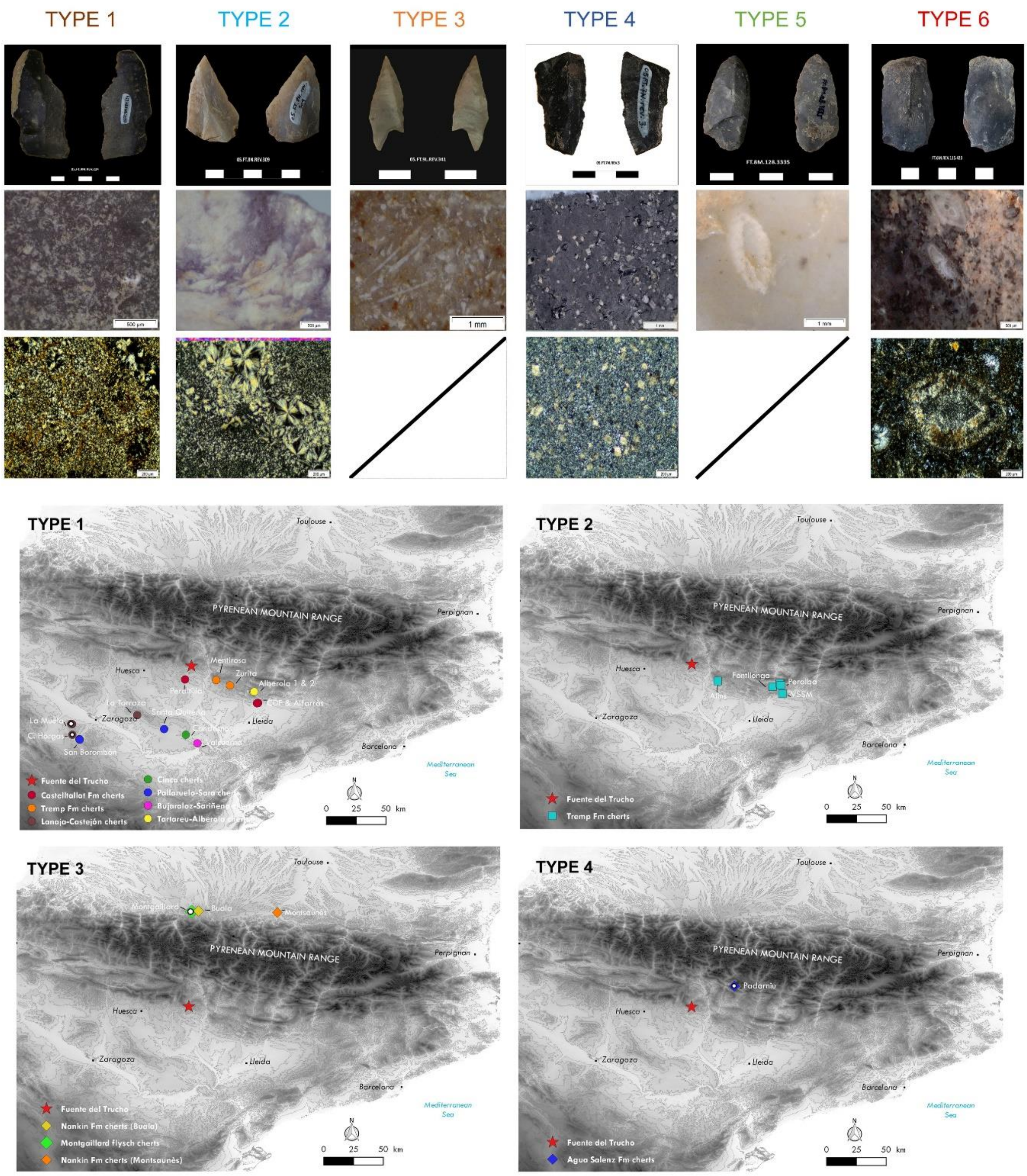


Figure 3 – Visual (up), macroscopic (middle) and petrographic (bottom) views of each chert type and location of the archaeological site and the formations containing cherts macroscopically similar to types 1 to 4. The black and white point in some outcrops indicates the outcrops that geochemically fit with the chemically analysed archaeological samples.

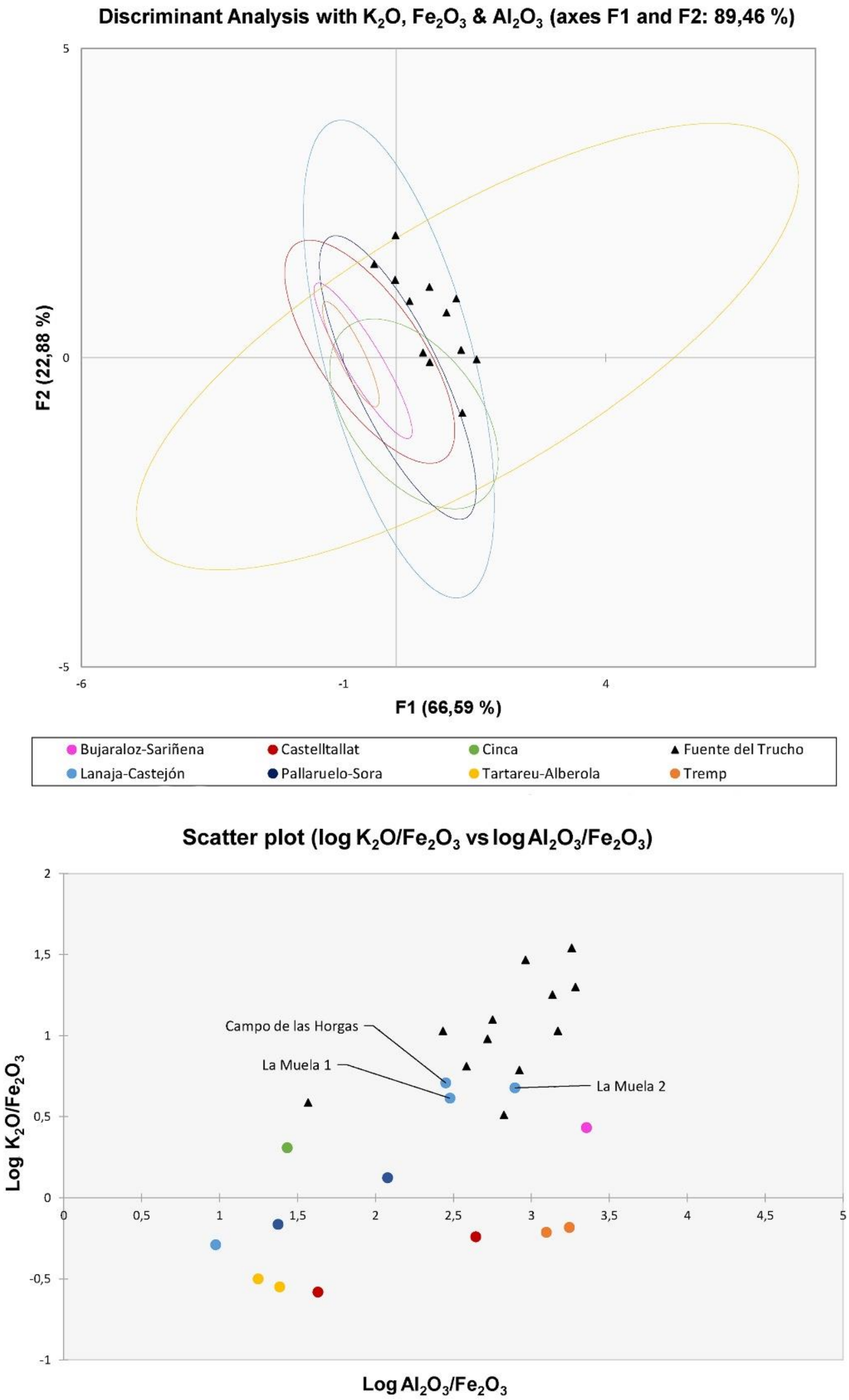
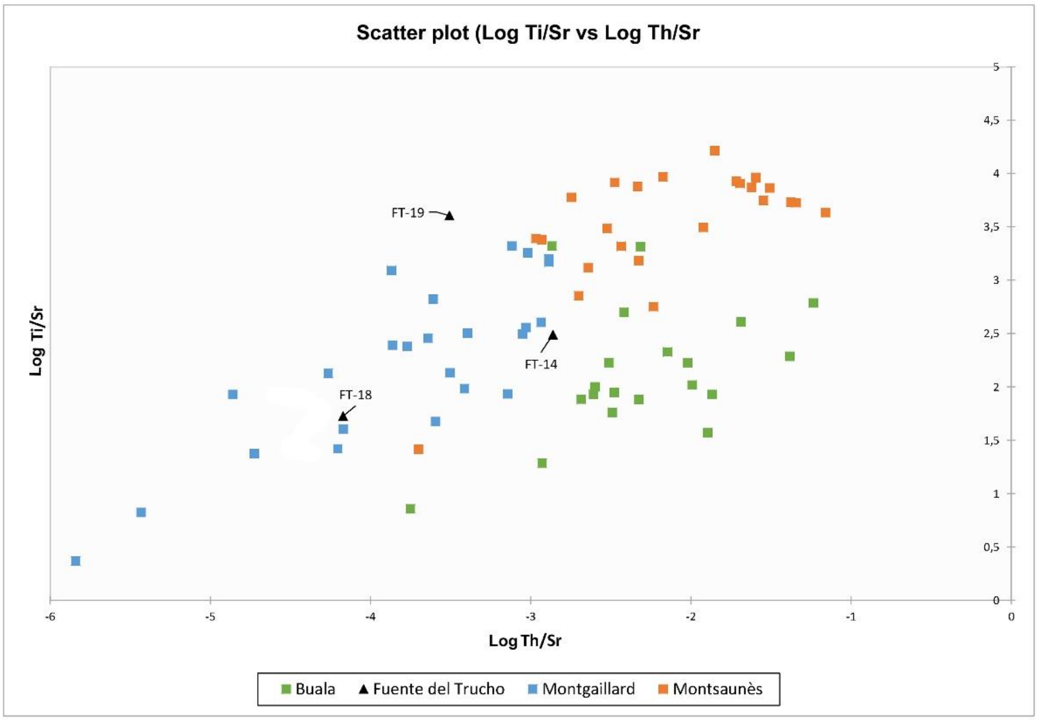


Figure 4 – DA plot for ED-XRF data with the archaeological samples from type 1 and the ellipses for each geological formation (up) and scatterplot for ED-XRF data concerning log K_2O/Fe_2O_3 vs log Al_2O_3/Fe_2O_3 with the archaeological samples from type 1 and the median values of the compared geological outcrops (bottom).



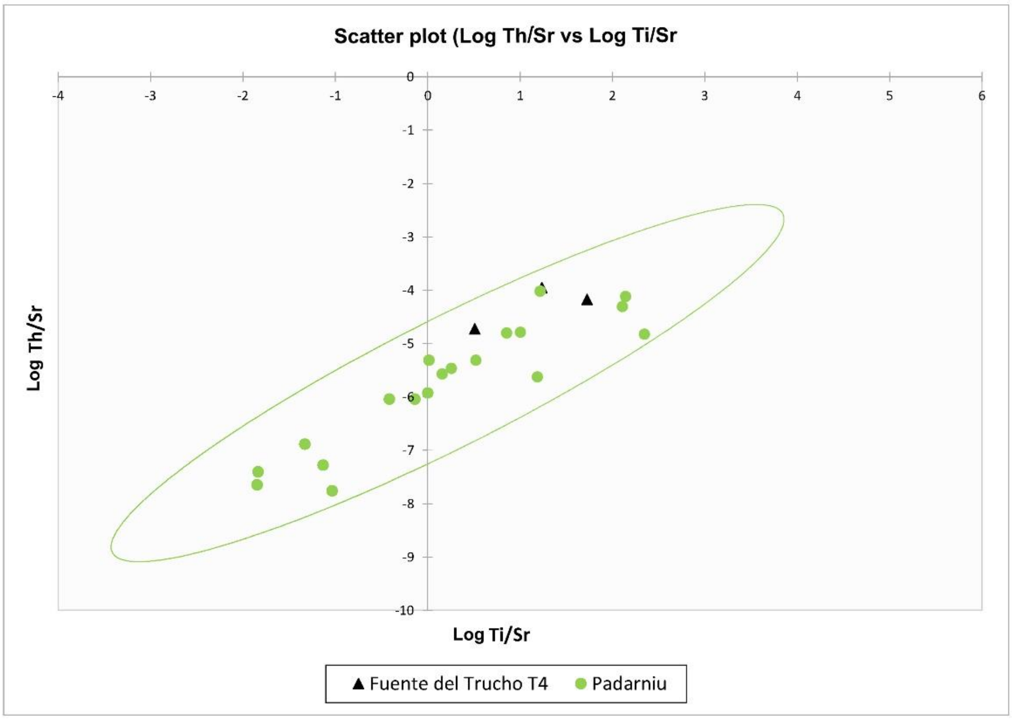


Figure 5 – Scatterplot with LA-ICP-MS data concerning log Ti/Sr vs log Th/Sr with the archaeological samples from type 3 and the compared geological outcrops (Montgaillard, Montsaunès and Buala) (top) and scatterplot with LA-ICP-MS data concerning log Th/Sr vs log Ti/Sr with the archaeological samples from type 4 and the compared geological outcrops (Padarniu). In green line, 95% confidence ellipse for the geological cherts from Padarniu (bottom).

Table 1 – Distribution of the lithic remains by lithologies and levels.

OUTCROP	MUNICIPALITY-PROVINCE	FORMATION	ED-XRF	LA-ICP-MS
Castelló de Farfanya	Castelló de Farfanya (Lleida)	Castelltallat	51	0
Alfarràs	Alfarràs (Lleida)	Castelltallat	8	0
Peraltilla	Peraltilla (Huesca)	Castelltallat	23	0
Zurita	Zurita (Huesca)	Tremp	18	0
Mentirosa	Estadilla (Huesca)	Tremp	6	0
Puente Candasnos	Candasnos (Huesca)	Bujaraloz-Sariñena	23	0
Valcuerna	Peñalba (Huesca)	Torrente de Cinca	20	0
La Muela 1	La Muela (Zaragoza)	Lanaja-Castejón	20	0
La Muela 2	La Muela (Zaragoza)	Lanaja-Castejón	10	0
Campo de las Horgas	Muel (Zaragoza)	Lanaja-Castejón	20	0
La Torraza	Farlete (Zaragoza)	Pallaruelo-Sora	13	0
San Borombón	Muel (Zaragoza)	Pallaruelo-Sora	21	0
Santa Quiteria	Muel (Zaragoza)	Pallaruelo-Sora	12	0
Alberola 1	Alberola (Lleida)	Tartareu-Alberola	20	0
Alberola 2	Alberola (Lleida)	Tartareu-Alberola	16	0
Buala	Montgaillard (Hautes-Pyrénées)	Campanian-Maastrichtian flysch	20	20
Montgaillard	Montgaillard (Hautes-Pyrénées)	Cenomanian-Turonian flysch	25	25
Montsaunès	Montsaunès (Haute Garonne)	Nankin	25	25
Padarniu	Padarniu (Huesca)	Agua-Salenz	19	19
TOTAL			**370**	**89**

Table 2 – Mahalanobis distance calculation for all the lacustrine archaeological samples geochemically analysed by ED-XRF and the main geological groups based on Al_2O_3, CaO, Fe_2O_3, K_2O and SiO_2 values.

	Bujaraloz-Sariñena	Castelltallat	Cinca	Lanaja-Castejón	Pallaruelo-Sora	TR-01	TR-02	TR-03	TR-04	TR-05	TR-06	TR-07	TR-08	TR-09	TR-10	TR-11	TR-12	Tartareu-Alberola	Tremp
Bujaraloz-Sariñena	0	0,220	1,747	0,843	0,528	3,795	6,650	7,556	4,924	5,394	5,630	5,211	3,042	6,278	2,905	2,564	1,838	4,596	0,083
Castelltallat	0,220	0	1,909	0,696	0,586	3,222	5,991	6,996	4,794	4,920	5,240	4,652	2,606	5,634	2,556	2,363	1,678	3,643	0,334
Cinca	1,747	1,909	0	0,997	0,463	7,233	5,874	4,279	1,143	4,640	3,315	5,805	5,353	9,634	4,043	1,313	1,232	2,621	2,532
Lanaja-Castejón	0,843	0,696	0,997	0	0,332	2,866	3,144	3,407	2,268	2,270	2,207	2,515	1,808	4,583	1,206	0,511	0,268	2,071	1,388
Pallaruelo-Sora	0,528	0,586	0,463	0,332	0	4,615	5,031	4,858	2,316	3,928	3,473	4,395	3,256	6,799	2,555	1,188	0,774	2,436	1,004
TR-01	3,795	3,222	7,233	**2,866**	4,615	0	3,018	6,525	8,740	2,749	4,864	1,433	0,273	0,472	0,878	3,694	3,131	5,726	3,924
TR-02	6,650	5,991	5,874	3,144	5,031	3,018	0	1,134	4,031	0,097	0,718	0,307	1,813	2,449	1,035	1,673	1,899	**2,577**	7,752
TR-03	7,556	6,996	4,279	3,407	4,858	6,525	1,134	0	1,628	0,966	0,187	2,233	4,575	6,541	2,899	1,321	2,018	**2,190**	9,077
TR-04	4,924	4,794	**1,143**	2,268	2,316	8,740	4,031	1,628	0	3,231	1,466	5,002	6,298	10,151	4,371	1,091	1,522	1,732	6,275
TR-05	5,394	4,920	4,640	**2,270**	3,928	2,749	0,097	0,966	3,231	0	0,450	0,280	1,527	2,538	0,702	1,032	1,236	2,324	6,439
TR-06	5,630	5,240	3,315	2,207	3,473	4,864	0,718	0,187	1,466	0,450	0	1,408	3,105	5,024	1,726	0,629	1,068	**1,720**	6,922
TR-07	5,211	4,652	5,805	**2,515**	4,395	1,433	0,307	2,233	5,002	0,280	1,408	0	0,696	1,137	0,348	1,732	1,718	3,184	6,008
TR-08	3,042	2,606	5,353	**1,808**	3,256	0,273	1,813	4,575	6,298	1,527	3,105	0,696	0	0,647	0,212	2,205	1,737	3,855	3,380
TR-09	6,278	5,634	9,634	**4,583**	6,799	0,472	2,449	6,541	10,151	2,538	5,024	1,137	0,647	0	1,263	4,758	4,250	6,524	6,557
TR-10	2,905	2,556	4,043	**1,206**	2,555	0,878	1,035	2,899	4,371	0,702	1,726	0,348	0,212	1,263	0	1,139	0,899	2,803	3,474
TR-11	2,564	2,363	1,313	**0,511**	1,188	3,694	1,673	1,321	1,091	1,032	0,629	1,732	2,205	4,758	1,139	0	0,109	1,383	3,494
TR-12	1,838	1,678	1,232	**0,268**	0,774	3,131	1,899	2,018	1,522	1,236	1,068	1,718	1,737	4,250	0,899	0,109	0	1,321	2,611
Tartareu-Alberola	4,596	3,643	2,621	2,071	2,436	5,726	2,577	2,190	1,732	2,324	1,720	3,184	3,855	6,524	2,803	1,383	1,321	0	5,642
Tremp	0,083	0,334	2,532	1,388	1,004	3,924	7,752	9,077	6,275	6,439	6,922	6,008	3,380	6,557	3,474	3,494	2,611	5,642	0