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Determination of lithic raw materials in Cantabrian Spain during Greenland Stadial 2: The Magdalenian of Tito Bustillo Cave (Ribadesella, Asturias)

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ABSTRACT

The lithic assemblage studied here comes from the space known as the *Área de Estancia* in Tito Bustillo Cave (Ribadesella, Asturias, Spain), a representative Magdalenian site. The remains were found in Sub-level 1c2 in the Lower Complex (1LC), which was excavated by J.A. Moure Romanillo from 1981 to 1983 and is associated with abundant evidence of osseous industry, fauna, portable art, etc. The present study is especially innovative because it introduces a holistic approach to the understanding of the management of lithic resources by hunter-gatherer groups in the late Pleistocene. It establishes the two main groups of raw materials in the assemblage (flint and quartzite) and the different types through a petrographic description, and the different procurement strategies that were employed. Some preliminary results about the functionality of these tools are also offered. The occupants of this cave during the Greenland Stadial 2 traced a diversified and complex dynamic of exploitation of lithic resources that combined both the most immediate, easily available and in greater volume (for example, quartzite and Piloña flint), and the most distant, of good knapping quality (Flysch flint, fundamentally). This circulation of raw materials is parallel to the patterns detected in other deposits in the region with a similar chronology. Significant differences are observed in the knapping schemes between raw materials based on the production of blanks for the manufacture of tools, whose typological classification and analysis of use-wear makes us propose a specialized and little diversified functionality, which is usually related to that of temporary occupations.

1. Introduction

The development and systematization of research on the petrological determination and provenance of lithic raw materials found in archaeological deposits expanded significantly in the Iberian Peninsula at the turn of the century, when several doctoral theses on the topic were submitted (e.g., Terradas, 1997; Sarabia, 1999; Tarriño, 2001; Mangado, 2002).

Since then, further results of prehistoric research programmes in Cantabrian Spain have been published, applying the methodological proposal based on the petrological characterization of the rocks. Over time, this has enabled a more detailed knowledge of the outcrops that could potentially have been used as sources of raw materials for hunter-gather groups in the Cantabrian Zone (Herrero-Alonso, 2018; Prieto, 2018), in the Vasco-Cantabrian basin (Tarriño, 2006; Rissetto, 2009; García-Rojas, 2014; Fontes, 2016a) and the Western Pyrenees (Elorrieta,

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2016; Calvo, 2019).

Many of these studies have focused on occupations dated in the Lower Magdalenian (ca. 19.0–18.2 ka cal BP), above all in the eastern sector of Cantabrian Spain (Fig. 1). The sites attributed to this period whose raw materials, especially the different flint types, have been studied are El Linar (Level 3), Las Aguas (Level B), Cualventi (Level E) (Tarriño, 2016), Altamira (Level 2 and *Obermaier Collection*) (Tarriño et al., 2013a; Fontes et al., 2016), El Juyo (Level 6), El Rascaño (Level 4b) (Fontes et al., 2016) and El Mirón (Level 17 of the Outer Vestibule or "Cabin" and Level 504 of the Vestibule Rear or "Corral") (Fontes et al., 2016, 2018) in Cantabria; and Santimamiñe (Level Csn-Camr) (Tarriño, 2011), Antoliñako koba (Level Lgc inf) (Tarriño and Aguirre, 2002), Praileaitz I (Level IV) (Tarriño, 2017) and Urtiaga (Level F) (Fontes, 2016b) in the Basque Country.

In the central sector, fewer studies have been carried out on archaeological lithic raw materials, even though in that geographic area the study of La Riera Cave (Asturias) was a pioneer in its approach to the classification of lithic resources into types based on their petrographic description and analysis (Straus et al., 1986). Other sites in Asturias where raw materials analysis, also focused on the identification of the different flint types, have been applied to Middle Magdalenian at Las Caldas – Chamber II (Levels IX, VIII and VII) (Corchón et al., 2009), and to Lower Magdalenian at El Cierro (Level F) (Álvarez-Fernández et al., 2016) and Cova Rosa (Layer 4 = CR2) (Álvarez-Fernández et al., 2020, 2021), although in those cases with quite limited samples (Fig. 1). To date, the geoarchaeological studies carried out in this region to identify quartzite resources have concentrated on Middle Palaeolithic occupations, basically because of the greater quantitative importance of that raw material (Prieto, 2018; Prieto et al., 2019, 2020, 2021).

The situation regarding functional studies is similar. This type of research has been applied to very few Lower Magdalenian sites in Cantabrian Spain: the nucleiform endscrapers from Level F in El Cierro Cave (Álvarez-Fernández et al., 2016), Levels 4 and 5 in El Rascaño Cave (Domingo et al., 2012), Level 17 in the Outer Vestibule or "Cabin" at El Mirón (Straus et al., 2016), and finally the chipped lithic remains in Level IV in the cave of Praileaitz I (Clemente-Conte et al., 2017).

The first results regarding the management and provenance of the raw materials in the lithic assemblage from Sub-level 1c2 in the Lower Complex (1LC) in the *Área de Estancia* in Tito Bustillo Cave (Ribadesella, Asturias) are presented here, as well as a first approach to the function of those implements at the site. These archaeological materials were found in the excavations performed by J.A. Moure Romanillo from 1981 to 1983. They are currently deposited in the Department of Prehistory, Ancient History and Archaeology at the University of Salamanca and in Asturias Archaeological Museum (Oviedo). The radiocarbon dates for Sub-level 1c2 situate this occupation in Greenland Stadial 2.

2. Tito Bustillo Cave

2.1. Fieldwork in Tito Bustillo

Tito Bustillo Cave is located at the western end of the Cantabrian Range (Lat. 43° 27′ 35″ N. – Long. 5° 23′ 10″ W.), barely 200 m from the estuary of the River Sella and about 1 km from the modern coastline. The cave follows a linear passage on an east–west direction approximately 550 m in length. The Cave was made known to the scientific community in 1968, the date on which the Torreblanca Caving Club discovered its cave paintings and engravings (Díaz García and Mallo Viesca, 2018).

In 1970, M.A. García Guinea carried out a series of trial excavations in the so-called *Conjunto XI*, near what was thought to be the original entrance hall of the cave, which was blocked by a collapse (García Guinea, 1975). These excavations succeeded in documenting several occupations ascribed to the Magdalenian.

J.A. Moure Romanillo continued the fieldwork in the same part of the cave, today called the *Área de Estancia*, from 1972 to 1986. In an excavation covering a surface area of about 27 m^2 (Moure Romanillo, 1975, 1990, 1997; Moure Romanillo and Cano, 1976), were differentiated in Level 1 and Level 2.

In 2020 and 2022, the sections left by the excavations in the *Área de Estancia* in the 1970s and 80s were cleaned and straightened, and samples were collected to obtain more information about the occupations in that part of the cave (Álvarez-Fernández et al., 2022).

Apart from these investigations in the inner area near the prehistoric entrance to the cave, excavations have been carried out in other parts of the cave: In the outer part of said entrance (Díaz García and Mallo Viesca, 2018; Álvarez-Fernández et al., 2022) and in the *Sala del Gran Panel Polícromo* or *Conjunto X* (García Guinea, 1975; Moure Romanillo, 1990). More recent excavations have been carried out in the *Galería de los Antropomorfos*, in *Conjunto XI*, in *El Coxu* and *Interior* (Balbín Behrmann et al., 2022).

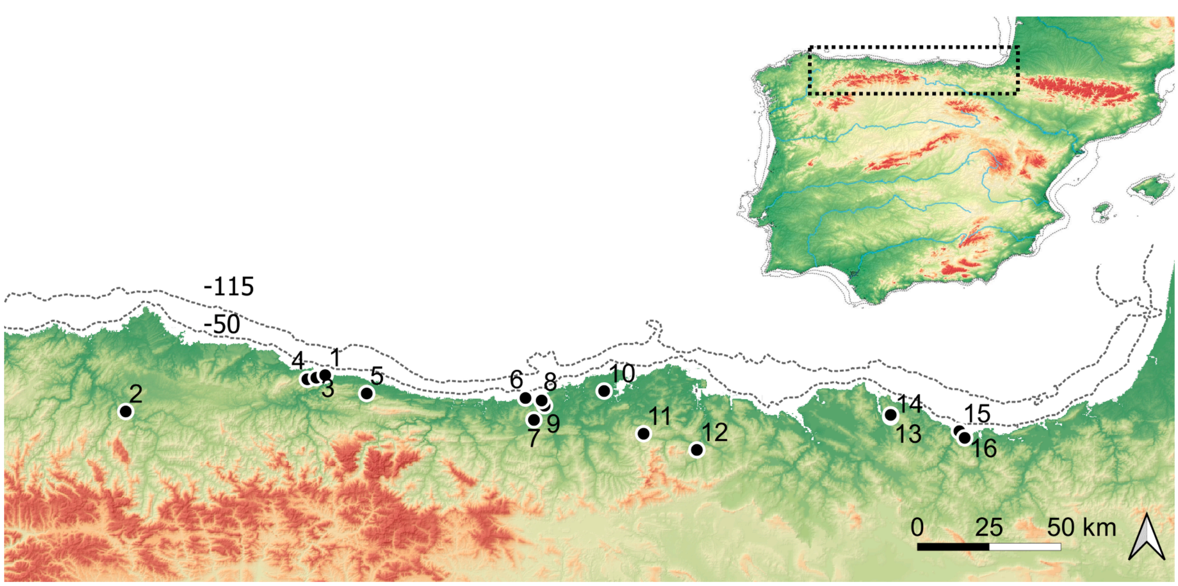

Fig. 1. Archaeological sites dated during Greenland Stadial 2 (Lower and Middle Magdalenian) in Cantabrian Spain with petrological determination of lithic raw materials. 1. Tito Bustillo; 2. Las Caldas; 3. El Cierro; 4. Cova Rosa; 5. La Riera; 6. Las Aguas; 7. El Linar; 8. Cualventi; 9. Altamira; 10. El Juyo; 11. El Rascaño; 12. El Mirón; 13. Santimamiñe; 14. Antoliñako koba; 15. Praileaitz I; 16. Urtiaga. The sea level contours are after Zickel et al. (2016).

2.2. Stratigraphy at Área de Estancia

The stratigraphy defined in the study by Moure Romanillo (1990) after his excavation in the *Área de Estancia* in Tito Bustillo Cave consisted of two archaeological levels. The upper Level 1 provided evidence of intense anthropic activity (Fig. 2).

Several combustion structures formed by burnt quartzite and limestone cobbles and charcoal remains were documented. The faunal remains are very abundant and indicate what type of subsistence activities the Magdalenian groups practiced: hunting (a specialization in deer is noted), fishing for salmonids and the gathering of marine invertebrates, mainly limpets (*Patella vulgata*) and periwinkles (*Littorina littorea*). The lithic artifacts (scrapers, armatures, etc.) were made mainly in flint and quartzite. The bone industry is characterized by a wide variety of tools (assegais, punches, spatulae, needles, etc.) made of cervid antlers and bones. These two materials, but also different rocks (schist, jet, etc.), teeth of herbivores and carnivores and seashells served as a support for the creation of a large number of personal ornaments and beads. Portable art has been elaborated on organic (bone and antler) and inorganic (sandstone plates) supports. They represent engraved figures of naturalistic animals, but also schematic, in addition to various signs (Moure Romanillo, 1990; Álvarez-Fernández, 2006, 2013; Álvarez-Fernández et al., 2018, 2022).

The pollen analyzes of Level 1 indicate its formation in a cold phase of the steppe type, with an abundance of heather and the predominance of grasses over ericaceas (Boyer-Klein and Leroi-Gourhan, 1987; Moure Romanillo, 1990).

Level 1 reached a maximum thickness of about 50 cm. It was divided into different sub-levels or layers based on a series of industrial and sedimentological characteristics, and these were later grouped into two complexes.

The Upper Complex (1UC), from 30 to 32 cm thick, included Sub-levels 1a, 1b and 1c1. Sub-level 1a was the surface layer and Sub-level 1b was formed by limestone rocks in the form of a 'pavement'. These sub-levels were not always continuous, so the contacts between them were called Sub-levels 1a-b and 1b-c.

The Lower Complex (1LC), 18 to 20 cm thick, grouped Sub-levels 1c2, 1c3 and 1c4.

These sub-levels that formed Level 1 were not found in all the squares that were excavated. Sub-level 1c2, studied here, was only documented in Squares XI.B, XI.C, XII.C and XIII.C.

Level 2 was a sedimentary layer formed by natural processes in the cave and possibly by occasional human presence, and contained very few archaeological remains, above all fauna (cervid bones and marine shells) and some osseous and lithic artefacts. Pollen data indicate a humid phase with a forest environment (pine, alder, birch and thermophilic trees) (Boyer-Klein and Leroi-Gourhan, 1987; Moure Romanillo, 1990). The information available for Level 2 is much scarcer since this level was only excavated in depth in squares XII.E and XIII.E.

2.2.1. AMS radiocarbon dating

A total of 15 radiocarbon dates have been obtained for the different sub-levels forming Level 1 in the *Área de Estancia* in Tito Bustillo Cave (Moure Romanillo, 1997; Álvarez-Fernández et al., 2015). They date the deposit between 19.0 and 16.7 ka cal. BP. Bayesian modelling has determined more precisely the time of occupations between 18.5 and 17.6 ka cal. BP and it was not possible to discriminate the Upper and Lower Complexes statistically (Álvarez-Fernández et al., 2018).

Sub-level 1c2, in the Lower Complex, has been dated three times by the AMS 14C method (Table 1). Bayesian modelling dates this sub-level to between 18.3 and 17.7 ka cal. BP with 68.3 % probability (Álvarez-Fernández et al., 2018).

3. Methodology

3.1. Raw materials

The analytical protocol designed to characterise the flint types found in Tito Bustillo Cave is based on the proposals previously put forward for the study of raw materials (Tarriño and Aguirre, 2002; Tarriño, 2006, 2011, 2016, 2017; Tarriño et al., 2007a, 2007b,2013a, 2013b, 2015, 2016; Tarriño and Terradas, 2013; Herrero-Alonso, 2018; Herrero-Alonso et al., 2021b). The first step is the *de visu* observation of the colour, gloss, transparency, feel and cortex (primary, secondary and degree of rounding). Second, the texture and different inclusions, which may be mineral (detritic quartz, carbonates, sulphates and oxides) and organic (bioclasts), are observed with a stereomicroscope. Third, analysis of thin sections using a petrographic microscope can determine, following the proposal of Folk (1980): 1) orthochemical components: definition of the type of quartz and organisation of the crystals; 2) allochemical components: contents of bioclasts, intraclasts, peloids, ooids, cortoids, etc.; 3) relict minerals: carbonates, oxides, sulphates, silicates, etc.; 4) authigenic minerals: phosphates, carbonates, silicates, sulphurs, oxides, etc.; 5) volatile elements: water and organic matter; 6) alterations; and 7) porosity.

The methodology applied to the quartzite remains from Tito Bustillo is based on stereomicroscopic observation following the proposal of Prieto et al. (2020). Although the observations were not validated through direct inspection of artefact thin sections, the data acquired were applied to classify each artefact into the seven petrogenetic types as proposed by Prieto et al. (2019a): clastic fabric with matrix or non-quartz cement quartz-arenite (MA), clastic quartz-arenite (CA), syntaxially overgrown orthoquartzite (OO), sutured grain orthoquartzite (SO), bulging recrystallized quartzite (BQ), subgrain rotation recrystallized quartzite (RQ) and grain boundary migration recrystallized quartzite (MQ). The association of most features classified each quartzite into the

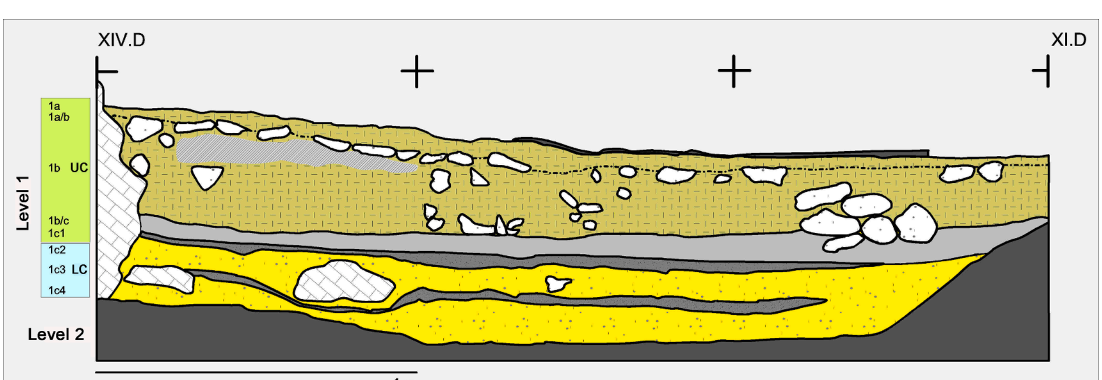

Fig. 2. Stratigraphic section (squares XIV.D-XI.D) of the *Área de Estancia* in Tito Bustillo Cave (modified by Moure Romanillo, 1997). UC: Upper Complex; LC: Lower Complex.

Table 1
AMS 14C dates for Sub-level 1c2 in the *Área de Estancia* in Tito Bustillo Cave. The AMS 14C results have been calibrated with OxCal 4.4 (Bronk Ramsey, 2009) using the IntCal20 (Reimer et al., 2020) and Marine20 calibration curves (Heaton *et al.*, 2020).

Level	Complex	Sublevel	Sample	Lab. Ref.	^{14}C	St. Dev.	Reference
1	1CI	1c2	Indet. Bone with cut marks	OxA-6262	14,680	110	Moure Romanillo (1997)
1	1CI	1c2	Indet. Charcoal	GrN-12753	14,930	70	Moure Romanillo (1997)
1	1CI	1c2	Marine Shell (*L. littorea*)	OxA-29117	15,570	55	Álvarez-Fernández et al. (2015)

	Calibrated (BP)			
	68.3 %		95.4 %	
	from	to	from	to
OxA-6262	18,171	17,868	18,231	17,560
OxA-29117	18,156	17,927	18,234	17,792
GrN-12753	18,277	18,184	18,610	18,100

aforementioned petrogenetic types, but also characterised the grain-size mean value and the non-quartz minerals. A reference collection was used based on 106 thin sections from quartzite artefacts and rock obtained in geological surveys in the Deva-Cares Valley (Prieto, 2018) and an on-going project in the proximity to Tito Bustillo Cave. The cortical areas were characterized by adapting the proposal made by Fernandes et al. (2007) to the quartzites in the area, following Prieto et al. (2021). These data were applied to relate the features with specific and potential raw material sources but, especially, to identify different raw material units.

Lithic raw materials can be classified based on the distance between the outcrops or potential supply areas and the archaeological sites being studied. In this way, three management models have been proposed (Tarriño et al., 2015, 2016): 1) local resources, those located inside a radius which it is estimated that a person can travel in half a day, under 30 km. This model is sub-divided into proximate local (<15 km) and distant local (15–30 km); 2) regional resources: in turn sub-divided into proximate regional for distances equivalent to what a person can travel in a day and a half (30–60 km) and distant regional, for distances that can be covered in less than three days' walking (60–120 km); and 3) tracer resources: those that were transported over a distance that a person can walk in a time of between three days and a week (120–250 km). Resources that come from sources more than a week's trek away (>250 km) are called super-tracers.

3.2. Technological study

The technological study has been based on groups, like other previous studies of chipped lithic assemblages (Fuertes-Prieto, 2010; Herrero-Alonso, 2018; Herrero-Alonso et al., 2020, 2021a):

- Group 0: unknapped nodules or blocks of raw materials. This group is representative of the procurement phase and implies the transport of materials that have not been worked.
- Group 1: flakes with (Group 1a) or without cortex (Group 1b): It includes both the objectives of reduction in the flake operative chains (flakes without cortex or marginal cortex) and the initial steps of the use of cores in flake and blade operative chains.
- Group 2: blades and bladelets produced by laminar reduction, as well as products related to the maintenance and self-maintenance of laminar reduction, such as blades with flank.
- Group 3: shaping products (arrises, crests and semi-crests, core flanks, etc.) representing the preparation sequences in the production phase.
- Group 4: cores. The study of the technical forms of the cores (diacritical interpretation) is a key indicator of the organisation of the reduction and is able to determine the objectives of production.
- Group 5: indeterminate pieces and broken elements generally larger than a centimetre. These are pieces that are difficult to interpret technically and may derive from different phases of both the preparation sequences and maintenance.
- Group 6: debris, knapping flakes and fragments smaller than a centimetre. They may derive from the reduction and shaping sequences in any phase (from preparation to production and correction) as well as the retouching phase. The fragments may also have been produced by post-depositional processes (such as trampling) affecting the assemblage. Nonetheless, a high percentage of debris is a good indicator of the intensity of the reduction of a material.
- Group 7: it includes the remains related to retouching, especially burin spalls but also fragments of retouched objects.

The management of lithic raw materials used in Tito Bustillo Cave have been classified depending on the degree of completeness of their operational chain: complete, incomplete or broken.

3.3. Typological study

The typological study has followed the classic criteria established in the type-lists of Sonneville-Bordes and Perrot, 1954, 1955, 1956a, 1956b. Retouched artefacts have been studied in terms of the length, angle, morphology, orientation, location, distribution and delineation of the removals from the edges.

3.4. Use-wear analysis

The methodology used in the functional study is based on a long tradition of previous studies aimed at identifying the use-wear on flint implements (Semenov, 1964; Keeley, 1980; Mazo, 1989; González-Urquijo and Ibáñez Estévez, 1994, among others). In addition to the specialised literature, the observed use-wear on the remains from Tito Bustillo has been compared with the experimental collection of one of the authors (CL) (López-Tascón et al., 2018; López-Tascón, 2022).

The microscopic analysis of siliceous surfaces aims to determine what the tools were used for and with. Traces related to technological and post-depositional processes are also identified. The equipment employed has been a stereomicroscope with 6.6 to 40× magnification to study macroscopic use-wear, such as micro-flaking and rounding. An optical microscope at 40–500× magnification was used to identify micropolish and striations, to determine the substance worked with the tools.

The objects were cleaned by applying a gentle cleaning protocol, using water, neutral pH soap and pure acetone. However, the identification codes have not been removed from their surfaces, which has caused some problems. The presence of these codes has hindered the microscopic analysis of many of the bladelets.

4. Results

2,178 lithic objects were recovered from Sub-level 1c2 in the *Área de*

Estancia in Tito Bustillo Cave. Two groups of raw materials in the lithic assemblage have been differentiated: quartzite and flint. In addition, the assemblage contains a few objects in quartz.

4.1. Raw materials: Flint

The study of the flint in the lithic assemblage from Sub-level 1c2 was performed on 1,102 remains from Squares XI.B, XI.C, XII.C and XIII.C (Figs. 3 and 4).

4.1.1. Local resources

4.1.1.1. Alba radiolarite. Its wide geographic distribution makes Alba radiolarite a well-represented material (6.62 %) but, equally, a very poor marker of territorial mobility. It is a variety formed in the Visean (Lower Carboniferous), which outcrops in the middle and upper members of the Alba Formations (Wagner et al., 1971). The presence of this siliceous variety has been known since the late 20th century and it has been identified at several archaeological sites in northern Spain. However, it had not been described from the petrological, mineralogical and geochemical points of view until recently (Tarriño et al., 2015; Herrero-Alonso, 2018; Herrero-Alonso et al., 2021b). All the Alba radiolarite at Tito Bustillo comes from the middle member, characterised by very regular parallel lamination and the presence of radiolarians. The joint extinction of the phyllosilicates can also be appreciated in thin sections.

4.1.1.2. Piloña flint. This is one of the main raw materials used in the assemblages (19.15 %). The capacity of this variety as a market of territorial mobility is weak. It outcrops in the Santonian limestone (Upper Cretaceous) in environments of the outer marine platform, in the valley of the River Piloña, a tributary of the Sella, but is also found in derived position in the Eocene-Oligocene continental conglomerates in the 'Posada pudding-stone' in the Oviedo Tertiary basin (Asturias). This flint, whose texture, mineralogy and geochemistry have been described (Tarriño et al., 2013b), is characterised by its contents of terrigenous minerals (mainly, quartz and muscovite) and bioclasts of miliolids (*Lacazina* genus). It is often found at archaeological sites in Asturias (Tarriño et al., 2015; Duarte et al., 2016).

4.1.1.3. Fito chert. Fito chert is generally used less, due to a more restricted geographical distribution than in the case of radiolarite, and appears in token proportions (0.18 %). However, this makes it a better marker of territorial mobility. The chert in the Fito Formation outcrops at the head of the River Ponga, another tributary of the Sella, in carbonate facies of the Podolskian / Myachkovian (Upper Carboniferous) formed in a transition from a prograding delta to a subsiding platform. References to silicifications in this geological formation are very scarce and only appear in a report (Bahamonde, 1989), while the first textural, mineralogical and geochemical description has been very recent (Herrero-Alonso, 2018; Herrero-Alonso et al., 2021b). The most important characteristic of this variety is a lenticular lamination with frequent bioclasts and dolomite idiomorph crystals, creating a variety with a distinct brownish and blackish hue.

4.1.2. Regional resources

4.1.2.1. Las Portillas chert. Las Portillas chert is a poorly represented raw material (0.18 %) because of its small distribution area. This resource outcrops in a very specific place in northern Spain, near Espinama (Cantabria) and is therefore an excellent marker of territorial mobility. It formed in a shallow marine platform in the transition from the Famennian (Devonian) to the Tournaisian (Lower Carboniferous). As in the case of Fito chert, references to this variety of siliceous rock are limited, apart from a study by Raven (1983) with a description that is no longer used. It is characterised by a very homogeneous matrix, with a very intense vitreous gloss and frequent presence of detritic accessory minerals (quartz, tourmaline, zircon, etc.) (Herrero-Alonso, 2018; Herrero-Alonso et al., 2021b).

4.1.2.2. Monte Picota flint. Monte Picota flint is one of the most abundant raw material types (16.52 %). It outcrops mainly in the San Román syncline, near Mt. Picota on the coast to the west of Santander Bay (Cantabria). These silicifications are associated with an internal marine platform in the Maastrichtian (Upper Cretaceous). The most important characteristic of this flint is its chalcedonitic composition with abundant fissures and cementation of fibrous quartz and mega-quartz in addition to the usual idiomorph crystals of dolomite. This flint is found in significant percentages at several archaeological sites relatively close to the main outcrop (Tarriño et al., 2013a; Tarriño, 2016) and has been described in recent years (Herrero-Alonso, 2018).

4.1.2.3. Urgonian flint. The frequency of Urgonian flint is quite significant (5.99 %). This raw material outcrops in the carbonate Urgonian complex that is widely distributed across the central and eastern sectors of northern Spain, which means that it is a very poor marker of territorial mobility. It is associated with Upper Aptian – Lower Albian reef

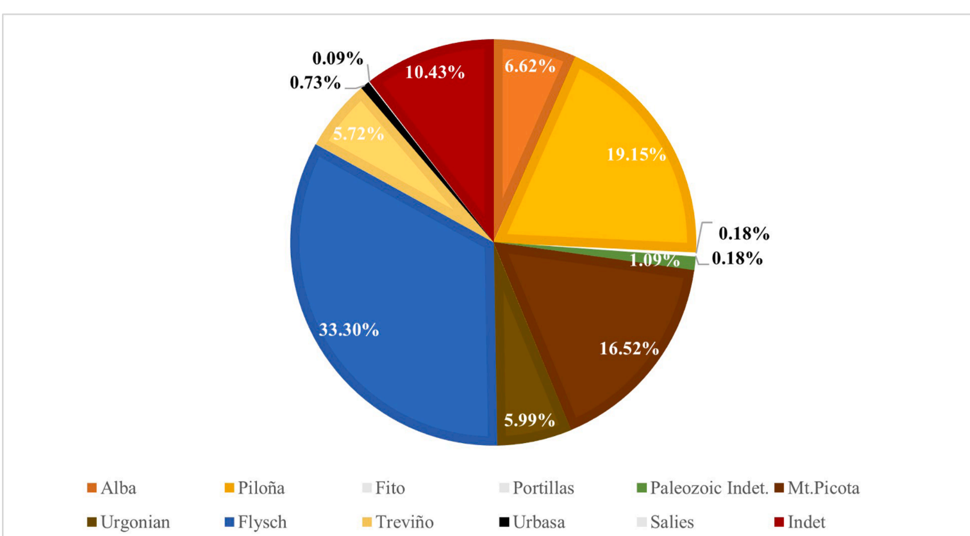

Fig. 3. Percentages of the flint types represented in the lithic assemblage from Sub-level 1c2 in the *Área de Estancia* in Tito Bustillo Cave (n = 1,102).

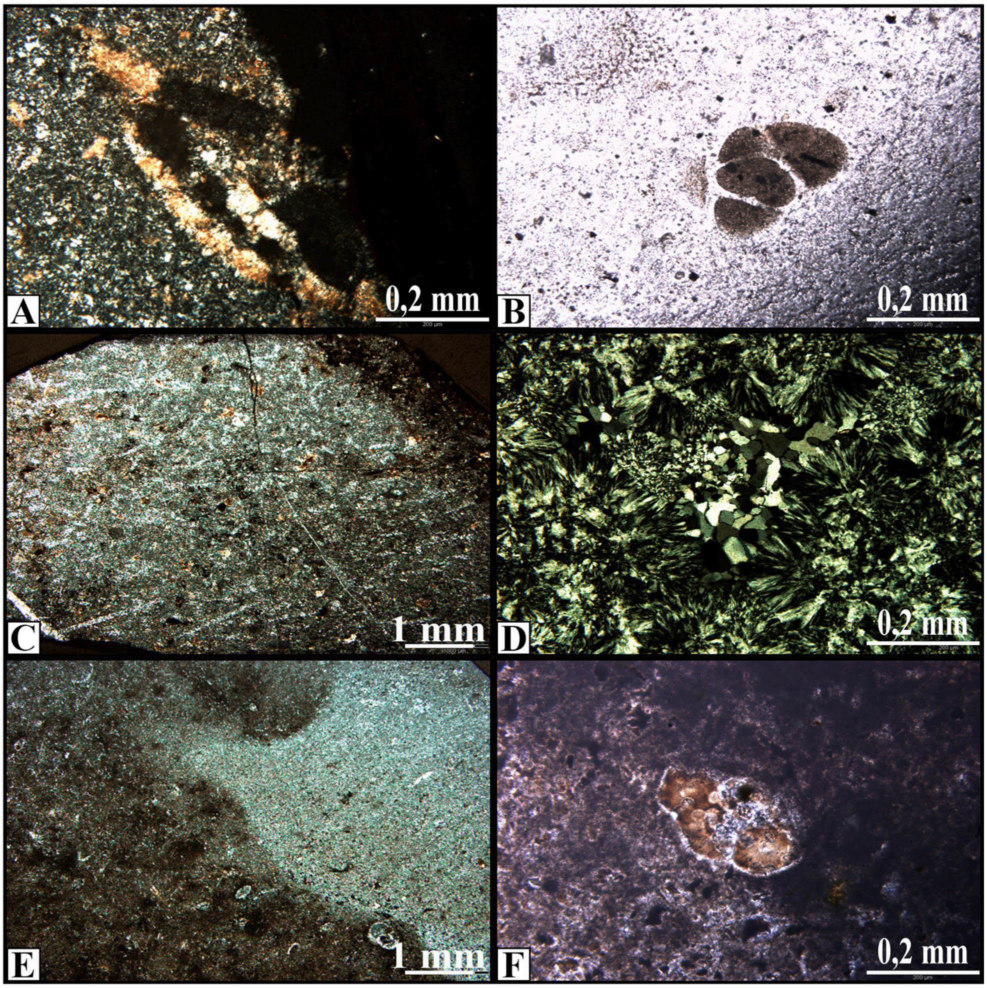

Fig. 4. Petrographic characteristics of some of flint types determined from the Sub-level 1c2 of Tito Bustillo. A. Detail of a possible benthonic foraminifera (genus *Nummulites*) with opalised internal chambers, crossed nicols. B. Detail of a planktonic foraminifera (family Globigerinidae) with opalised chambers and fibrous quartz walls, and ferruginised idiomorph crystals (rhomboids) of dolomite with a size of 20 μm, parallel nicols. C. General aspect of the texture characterised by a very bioclastic siliceous matrix with long-sections of sponge spicules, crossed nicols. D. Detail of siliceous matrix with cementations of fibrous quartz and a micro-geode with fibrous quartz walls and nucleus of mega-quartz crystals, crossed nicols. E. General aspect of the texture characterised by an interface between the siliceous matrix and the carbonate matrix, crossed nicols. F. Detail of a planktonic foraminifera (family Globigerinidae) in the carbonate matrix, with its internal chamber semi-opalised, parallel nicols.

platforms (Lower Cretaceous) (Bustillo et al., 2017). It is characterised by the presence of rudists and both massive and branching corals, among many other identifiable fossils. Although its use as a raw material has generally been considered testimonial, in recent years it has been detected in significant proportions at some Cantabrian sites (Fontes et al., 2016).

4.1.3. Tracer resources

4.1.3.1. Flysch flint. Flysch flint is the best represented siliceous raw material (33.30 %) and the Kurtzia Flysch variety has been identified with certainty. This resource comes from turbiditic geological formations deposited in deep environments at the foot of the slopes connecting the marine platforms with the pelagic ocean depths. Several varieties have been defined, corresponding to outcrops on both sides of the Pyrenees (Tarriño et al., 2015). They share a series of microscopic characteristics such as the high bioclast content (mainly the large number of sponge spicules), abundant detritic quartz of sand grain size and frequent idiomorph dolomite crystals. The Kurtzia variety comes from the Cenomanian-Santonian (Upper Cretaceous) in a very specific area near the coastal town of Barrika (Bizkaia) (Tarriño, 2006), which makes it one of the best markers of territorial mobility in Cantabrian Spain. It displays a characteristic turbiditic lamination with a generally translucent matrix affected by the stigmas of severe marine abrasion and is found in nearly all the sites that have been studied in northern Spain (Tarriño et al., 2016).

4.1.3.2. Treviño flint. Treviño flint appears in a quite significant proportion (5.72 %) and its four micro-facies have been identified. The nodular micrite with bioclasts is the most common variety in the archaeological deposit. This resource, which is a good marker of territorial mobility, outcrops in lacustrine-palustrine environments in the Miranda-Treviño basin, associated with the Miocene. It appears in the hills of the Sierra de Araico and its prolongation towards the north in the Cucho-Busto Hills (Tarriño, 2006). The variability in the context of the formation of these silicifications means that different micro-facies can be identified (Tarriño et al., 2015). At a microscopic scale, characteristic fossils of continental environments predominate (gastropods, ostracods, pedotubules, etc.). This resource has been documented at many archaeological sites in northern Spain (Tarriño et al., 2016).

4.1.3.3. Urbasa flint. Urbasa flint is represented with a testimonial percentage (0.73 %). Nonetheless, its value as a marker of territorial mobility is outstanding. This resource outcrops in the karst in the Sierra de Urbasa in Navarre (Tarriño, 2006). It is found with a nodular morphology. It formed in an outer marine platform and has been dated in the middle Thanetian (Palaeocene) by foraminifera: discocyclinids (*D. seunesi*) and nummulitids (*N. herberti*) (Baceta, 1996). It has been described from the petrological, mineralogical and geochemical points of view (Tarriño et al., 2007b). In addition to the high content of foraminifera and other bioclasts, such as the remains of echinoderms, one fundamental characteristic of this variety is its incipient micro-dolomitisation. Together with the Flysch and Treviño types, this flint was one of the main sources of raw materials on the southern side of the Western Pyrenees (Tarriño et al., 2007a).

4.1.3.4. Salies-de-Béarn flint. Although the appearance of Salies-de-Béarn flint is testimonial (0.09 %), like the previous case, it is an important marker of territorial mobility. This raw material outcrops in a Campanian carbonate series (Upper Cretaceous) exposed in the Peyrehorade anticline, associated with a deep marine basin, in the French Department of Pyrénées-Atlantiques (Tarriño et al., 2007a). It is a dark, fine-grained flint with bioturbations rich in relict carbonates that create a banded outer appearance in light greyish hues. Planktonic foraminifera are also usually present (Normand, 2002). This variety is mostly found at sites north of the Pyrenees, but has also been identified at several places on the southern side (Tarriño et al., 2015).

4.1.4. Indeterminate resources

Some flint artefacts could not be assigned a more or less exact provenance owing to several causes impeding their determination, either because of an alteration to the outer appearance of the matrix (fire, white patinas, etc.) resulting in micro-fissures, colour change and porosity, or difficulty in identifying the discriminant criteria or the lack of them. These objects were classified in the present study in the category of Indeterminate. These indeterminate flint remains represent an important percentage at Tito Bustillo (11.52 %).

In those cases when it was possible to make an approximate but not definitive identification, their possible places of provenance were noted. One small group of indeterminate remains might belong to the types known at the site, such as the Flysch and Urbasa flint types. However, most of the indeterminate remains possibly correspond to types whose presence could not be confirmed, such as Piedramuelle, Loza, Tercis and Chalosse flint.

4.2. Raw materials: Quartzite

The study of the quartzite was performed on a sample of 89 objects out of a total of 1,071 documented remains. They all come from Square XI.B.

The quartzite is quite variable and the seven petrogenetic types identified in other contexts were determined here by stereomicroscopic inspection. Several varieties were also identified. Orthoquartzites (OO and SO) are predominant, followed by metamorphic quartzites, mainly the BQ type and a few MQ and RQ artefacts. Quartz-arenites are similarly represented to metamorphic quartzites and they consist of MA (more abundant) and CA types.

In general, the artefacts in the MA type are extremely variable in quartz grain size, colour (brown, grey, black or white), non-quartz mineral content (micas, black and heavy non-identified minerals, manganese and iron oxides and feldspars) and the nature and the amount of cement and matrix. Moreover, this variability is also observable in MA individuals, emphasising the intrinsic heterogeneity of this type. However, a frequent variety with fine quartz grains and abundant clayey and ferruginous cement between grains was detected. Different colour and mineral varieties in CA quartz-arenites were also detected, all of them with heterogeneous quartz grain-size distributions. In this case, the small relicts of cement and matrix do not display differences although the absence of thin sections could have impeded their discrimination. Regarding the orthoquartzites, there are two varieties of OO type according to the colour/mineral characterisation: grey-white (more common) and black (less common). The latter is associated with pyrites and manganese oxides. One of the quartzites of this type differs from previous varieties due to its red colouring and the presence of circular structures associated with pyrites, iron and manganese oxides. In general, all OO orthoquartzites have medium grain sizes with heterogeneous distributions and they can be related to the increase in grain size motivated by the syntaxial quartz overgrowths, as observed in thin sections of rocks formed in similar genetic conditions (Bastida, 1982; Thiry and Milnes, 2017; Prieto et al., 2019b). In the white variety, some grains show ruffled, irregular and thin limits on flat reliefs, originated as a consequence of an increase in the deformation processes that promotes sutures between quartz grains, favouring knapping properties. In the SO type, there are two varieties, the light-grey one, with fine quartz grains (more common); and another with foliated structures, dark blue-grey colour and coarser quartz grains homogeneously distributed. Pyrites and dense iron oxides are frequent in the inner and cortical quartzite surfaces of the second type but they are less frequent in the inner part of the first variety. Again two BQ quartzite varieties were identified: a black one, with pyrites, iron, manganese oxides and fine quartz grain sizes and a white one, associated with medium quartz grain sizes. Both have foliation structures. The last feature is also common to the RQ and MQ type, but, probably due to their small numbers, no specific varieties were observed.

Cortex is preserved on half of the artefacts, generally on surfaces smaller than 33.0 %. Iron oxide precipitates (also pyrites) in voids or above the alluvial neocortex derived from the clayey sediments of the site hinder the identification of cortical surfaces because these precipitates constitute a relevant marker to determine the conglomerate neocortex (Fernandes et al., 2007; Prieto et al., 2021, 2022). This causes a high quantity of non-identified surfaces (≈40.0 %) and also forces us to nuance the conclusions given. Two-thirds of identified cortex is derived from fluvial deposits, few quartzite artefacts have neocortex derived from conglomerates and only one derived from a massive exposed quartzite outcrop. Neocortex from conglomerates was characterised in orthoquartzites and quartzites. Preliminary data suggest that all these quartzite types could be procured in 30 km radius conglomerate formations and in fluvial deposits.

4.3. Lithic technology

The technological study of the lithic assemblage was carried out for a total of 1,102 flint objects (Table 2). It should be noted that this study of the artefacts has not quantified either the quartzite or quartz remains, which are currently being studied in greater detail by one of the present authors (AP). For the flint artefacts, a number of differences have been observed in the management of the various types and their reduction process (Fig. 5).

A complete operational chain has only been identified in Alba radiolarite, in which flakes (50.68 %) are more numerous than blades (13.70 %) in a significantly higher proportion than in the other flint types. The high percentage of Group 3 remains, consisting of preparation and debitage maintenance products (15.07 %) is also noteworthy. Most of the maintenance products are blade core flanks aimed at maintaining the *carénage* and *cintrage*, as well as restoring the flaking surface in the case of knapping defects (reflections, natural planes, etc.). Cortical flakes and first order flakes have also been documented and two natural cortical arrises have been identified. They were removed as a way to begin reduction, as seen previously in other assemblages with radiolarite (Herrero-Alonso et al., 2021a). Lastly, some bladelets with a crest or neo-crest linked to laminar production have also been identified. These are usually extracted to correct the central arris and facilitate reduction. Only one core used to produce bladelets has been documented; it displays a well-delimited flank and bipolar extractions from two platforms.

Table 2
Technological inventory of the flint assemblage from Sub-level 1c2 in the *Área de Estancia* in Tito Bustillo Cave.

Group	Retouched	Non retouched	Total
0 – Nodules	0	0	0
1 – Flakes	31	250	281
2 – Laminar blanks	170	480	650
3 – By-products	1	28	29
4 – Cores	1	12	13
5 – Indeterminate pieces	1	59	60
6 – Debris	0	60	60
7 – Burin spalls	0	9	9
Total	204	898	1102

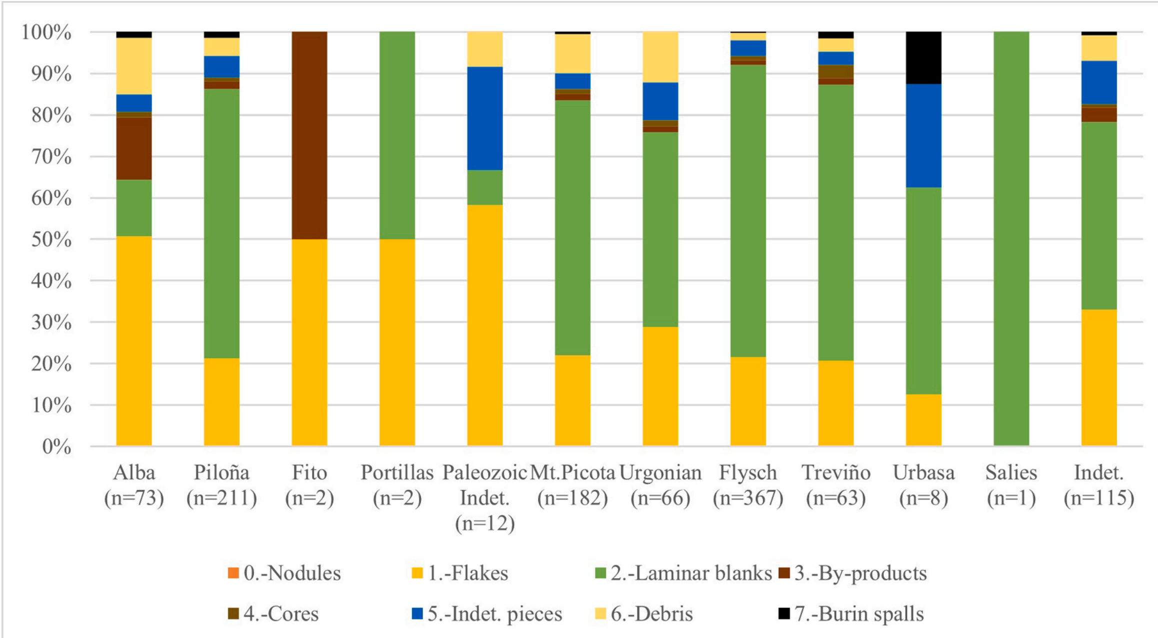

Fig. 5. Percentages of the technological groups represented in the flint assemblage from Sub-level 1c2 in the *Área de Estancia* at Tito Bustillo Cave (n = 1,102).

Incomplete operational chains have been observed in the flint types: Piloña (local), Monte Picota (regional), Urgonian (regional), Flysch (tracer) and Treviño (tracer). Their characteristics are very similar. Laminar blanks are more abundant than flakes and very few elements are linked to the initial reduction phases. Although some flakes with cortex are found, they are not abundant and no other elements are associated with initiating reduction. This practical absence of remains suggests that the cores reached the site in a more or less advanced stage of debitage. However, elements linked to maintenance of the technical process in later reduction phases, such as crests aimed at correcting the central arris and a semi-tablet, have been identified. Knapping waste is relatively scarce, albeit more common in the local and regional materials. The cores that have been identified, a total of 13, were used to produce flakes with discoid methods (Fig. 6: 2), and blades and bladelets (Fig. 6: 1). The latter cores are mostly prismatic with a single percussion platform and method of semi-surrounding and unipolar extractions. It should be stressed that whereas flake cores have been observed in the local and regional raw materials, in the tracer Flysch and Treviño flint types, production focused only on blade blanks and no flake cores have been identified.

Fig. 6. 1: Pyramidal Flysch flint and 2: Discoid Urgonian flint cores from Sub-level 1c2 in the *Área de Estancia* in Tito Bustillo Cave.

The broken operational chains appear in four flint types: two of Palaeozoic chert (Fito, local; and Portillas, regional) and two of flint (Urbasa, tracer; and Salies-de-Béarn, tracer). In these cases, only prepared blanks are found (mainly blades and bladelets) and a few indeterminate objects, generally without cortex. This would suggest that these materials arrived as finished products or as cores shaped away from the site, ready for the occasional removal of blanks.

The size of the lithic objects has been studied with 252 whole remains, mainly flakes and blades. In general, certain homogeneity is seen in the assemblage, whatever the flint type, and most pieces are between 2.2 and 2.8 cm in length (Fig. 7). The exceptions are two blades in Urgonian flint that are much larger than the others, over 10 cm in length. The difference in size may be connected with the presence of other operational chains and reduction sequences, of which no other remains have been found in the sub-level, either because they were made outside the site or away from the area of the excavation.

The technological analysis of the sample of 89 quartzite objects only from Square XI.B shows interesting patterns, especially when this information is related to the geological features commented above. In the selected square metre, there is only one core, discoid or bi-pyramidal, displaying an intense degree of exploitation. One crest is configured in this core and it cannot be ruled out that the core was abandoned due to its small size before removing the crest. This core is made on the BQ type (black and small grain size variety) and has a small remnant of the cortex and a visible crack that hinders knapping activities. Besides, there are three core preparation/rejuvenation products (two crests and one flank) in the three main varieties of OO type, suggesting that knapping activities were (occasionally?) performed at the site using other petrogenetic types and varieties rather than the BQ type. Blanks mainly consist of flakes and some elongated flakes and only a few differences are observable in the products on different petrogenetic types. In this regard, more complex exploitation systems based on direct and longitudinal schemes are observable in all varieties of BQ and SO types, whereas most of the quartz-arenites were exploited less and based on expedient behaviour. The only exception is the MA type with fine grain and clayey/ferruginous cement which shows a more complex exploitation system.

4.4. Lithic typology

A total of 204 retouched artefacts in flint have been studied. After their individual observation and classification in the type-list, they have been grouped into different categories of artefacts (Table 3). The backed group is the most numerous and makes up over half the retouched assemblage (55.39 %). Objects with continuous retouching on one or two sides make up the second most frequent group (23.01 %) and burins represent the third most abundant category (8.82 %). Perforators and the group of notches and denticulates appear with the same percentages (4.41 %). The retouched assemblage is then completed by truncated objects (1.96 %), a simple endscraper, an endscraper-burin and another two artefacts in the Various category (Fig. 8).

The backed group (n = 113) (Fig. 9: 6, 7, 8 and 9) consists of a denticulated backed bladelet, made in Treviño flint, and a total of 112 backed bladelets: 41 in Flysch flint, 35 in Piloña flint, 17 in Monte Picota flint, six in Treviño flint, one in Urgonian flint and 13 in indeterminate types.

The group of objects with continuous retouching (n = 47) (Fig. 9: 3 and 4) is formed by five blades retouched on two sides (two in Flysch flint, two in Piloña flint, and one in Urgonian flint) and 42 objects retouched on one side. Six of these are flakes and the other 36 are blades. Of the flakes, four are in Piloña flint, one in Flysch flint and one in an indeterminate type. In turn, 17 blades are in Flysch flint, six in Piloña flint, four in Urgonian flint, three in Monte Picota flint, three in Treviño flint and the other three in indeterminate types.

The burin group (n = 18) (Fig. 9: 1 and 2) consists of seven straight dihedral burins on flakes (four in Flysch flint, one in Piloña flint, one in Urgonian flint and one in Treviño flint); two angled dihedral burins (one on a blade in Piloña flint and the other on a flake in Urbasa flint); four

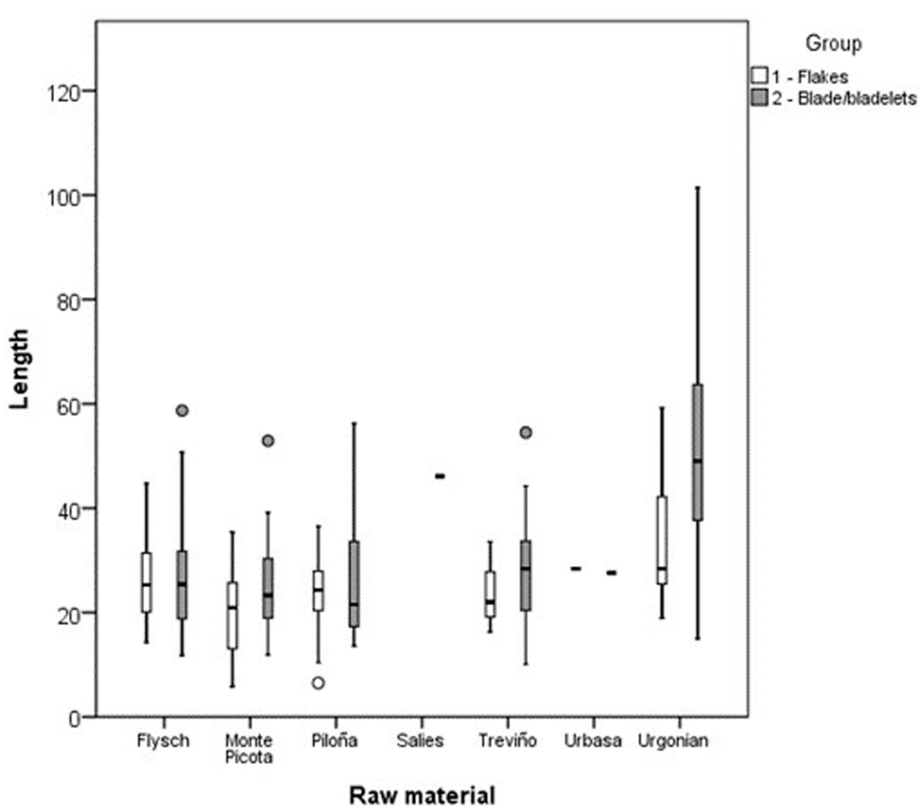

Fig. 7. Length of flakes (white) and blades (grey) in the flint assemblage from Sub-level 1c2 in the *Área de Estancia* in Tito Bustillo Cave (n = 252).

Table 3
Typological inventory of the flint assemblage from Sub-level 1c2 in the *Área de Estancia* in Tito Bustillo Cave.

Type-list	Classic Typology		Artefact categories	
	n	%	*n*	%
Simple endscraper	1	0.49 %	2	0.98 %
Endscraper-burin	1	0.49 %		
Perforator-burin	2	0.98 %	9	4.41 %
Perforator	7	3.43 %		
Straight dihedral burin	7	3.43 %	18	8.82 %
Angled dihedral burin	2	0.98 %		
Angle burin on break	4	1.96 %		
Multiple dihedral burin	1	0,49 %		
Burin on straight retouched truncation	1	0.49 %		
Burin on oblique retouched truncation	1	0.49 %		
Multiple mixed burin	1	0.49 %		
Core burin	1	0.49 %		
Straight truncation	2	0.98 %	4	1.96 %
Obliqued truncation	1	0.49 %		
Concaved truncation	1	0.49 %		
Piece with continuous retouching on one side	42	20,59 %	47	23.04 %
Piece with continuous retouching on two sides	5	2,45 %		
Notched piece	5	2.45 %	9	4.41 %
Denticulated piece	4	1.96 %		
Backed bladelet	112	54.90 %	113	55.39 %
Denticulated backed bladelet	1	0.49 %		
Various	2	0.98 %	2	0.98 %
Total	204	100.00 %	204	100.00 %

angle burins on a break (two on flakes and one on a blade in Flysch flint, and one on a blade in Monte Picota flint); a multiple dihedral burin on a Flysch flint flake; a burin on a straight retouched truncation on a Piloña flint flake; a burin on an oblique retouched truncation on a Monte Picota flint flake; a multiple mixed burin on a flake in Flysch flint; and a core burin in Flysch flint.

The perforator category (n = 9) (Fig. 9: 5) is formed by seven simple specimens and two perforator-burins. Of the former, four are on flakes: two in Flysch flint, one in Alba radiolarite and the other in an indeterminate type. The other three are on blades: one in Flysch flint, one in Urgonian flint and the other in Salies-de-Béarn flint. One of the perforator-burins is made from a Flysch flint flake and other on a blade in Monte Picota flint.

The notches and denticulates group (n = 9) comprises five artefacts with notches, of which one is on a Flysch flint flake, two on Flysch flint blades and two on Piloña flint blades, and four denticulated artefacts: one on a Flysch flint blade and the others on flakes in Alba radiolarite, Flysch flint and an indeterminate type.

The truncated group (n = 4) is formed by two objects with straight truncations, one on a flake and the other on a blade, both in Flysch flint; an oblique truncation on a Monte Picota flint flake; and a concave truncation on a blade in Urbasa flint.

The information compiled from the study of the retouched artefacts in quartzite in the sample from Square XI.B shows that retouching is very common in the quartzitic assemblage and more than a third of the objects are retouched. Of these, over half are burins, followed by side-scrapers, endscrapers, denticulates and one splintered piece. The absence of backed elements is relevant, especially when it is compared with flint assemblages. Orthoquartzites and quartzites were retouched most and the tool types were more varied than in the case of quartz-arenites, which were mainly retouched following the simple mode and in larger formats.

4.5. Use-wear analysis

The use-wear study examined a sample of artefacts made from the different flint types described here, from Squares XI.B, XI.C, XII.C and XIII.C.

In the case of the bladelets, one unretouched bladelet and 106 retouched bladelets were studied. These were a retouched reflected bladelet, a proximal fragment of a retouched bladelet, a denticulated backed bladelet and 103 backed bladelets, found in the different squares of Sub-level 1c2 in the Lower Complex (1LC) (21 from Square XI.B, 14 from Square XI.C, 63 from Square XII.C and five from Square XIII.C).

The unretouched bladelet was used to scrape dry hide. This is the only evidence of working with hide that has been documented in the sample.

The denticulate backed bladelet (Fig. 9: 6) does not display traces of use. However, the retouched area is slightly rounded in the raised parts of the denticulation. Remains of ochre were detected in the same area, which suggests that the bladelet was hafted in the retouched part.

The retouched reflected bladelet exhibits signs of being near a source of heat and traces related to a longitudinal action cutting hard matter, possibly bone, have been documented on its retouched right side. Similarly the proximal fragment of a retouched bladelet also displays

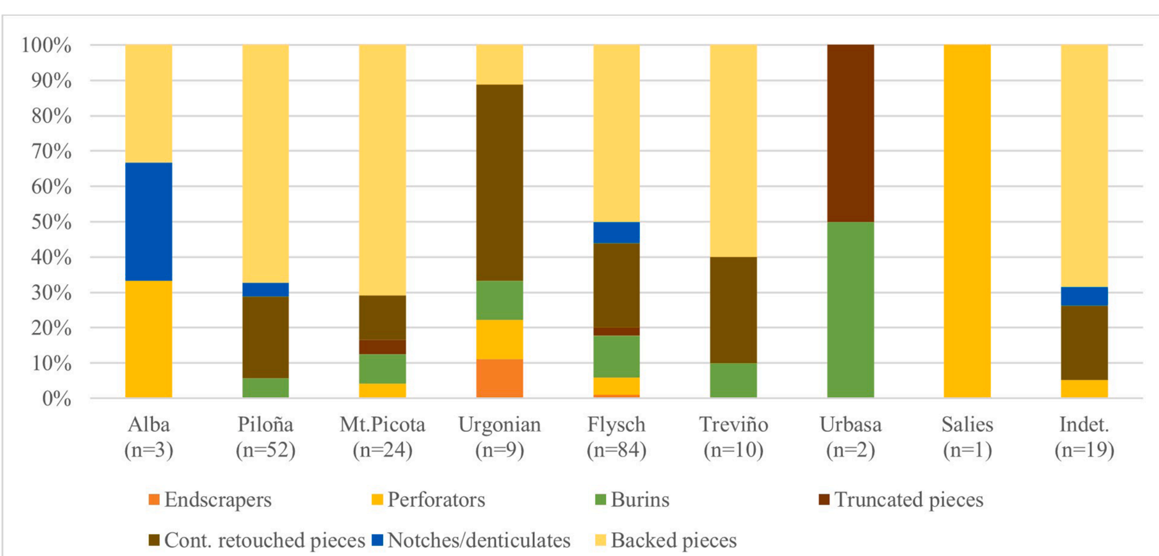

Fig. 8. Percentages of the typological categories represented in the flint assemblage from Sub-level 1c2 in the *Área de Estancia* in Tito Bustillo Cave (n = 204).

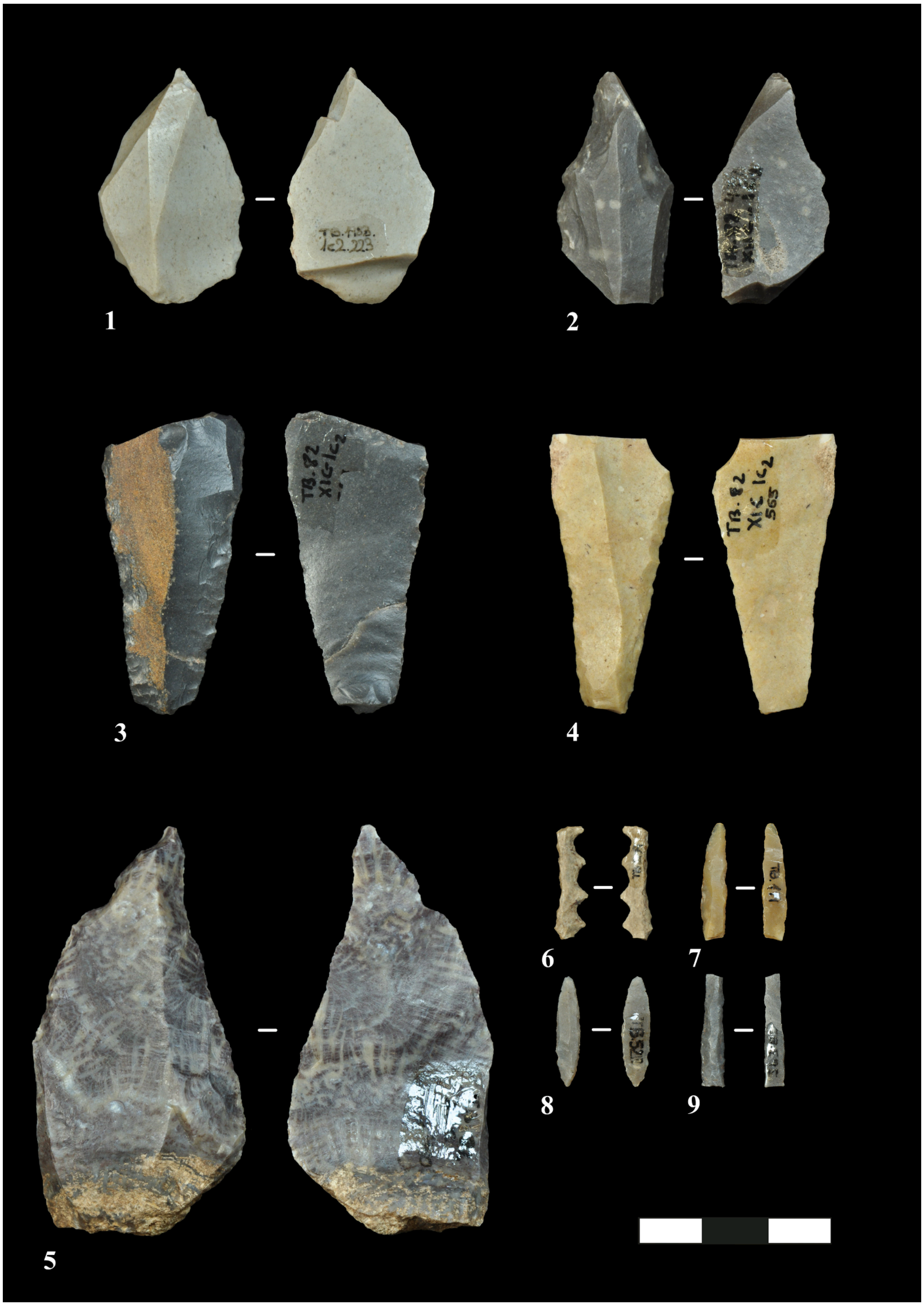

Fig. 9. Some of retouched artefacts in the flint assemblage from Sub-level 1c2 in the *Área de Estancia* in Tito Bustillo Cave. 1 and 2: Burins; 3 and 4: Blades retouched on two sides; 5: Perforator; 6: Denticulated backed bladelet; 7, 8 and 9: Backed bladelets. Raw material: 1, 2, 3 and 9: Flysch flint; 4 and 7: Piloña flint; 5: Urgonian flint; 6: Treviño flint; 8: Monte Picota flint.

micropolish related to cutting hard animal matter.

The backed bladelets do not show microscopic use-wear related to cutting hard substances or butchery tasks. This absence may be connected with the small size of the bladelets.

15 of them are complete (14.60 %), while the fragmented bladelets are divided into: 29 distal fragments (28.10 %), 15 proximal fragments (14.60 %) and 44 mesial fragments (42.70 %).

The fractures have been classified following the criteria proposed by O'Farrell (1996). Most of the fractures were caused by flexion (98.50 %). Many of them are straight or simple fractures (79.70 %) possibly caused by post-depositional processes like trampling or by their use, although this cannot be affirmed for certain. Diagnostic fractures indicating their use as projectile elements (burin-like and spin-off) have only been documented on 13.30 % of the bladelets, so it may be imagined that these objects reached the site inside the prey that had been hunted. Finally, fractures classified as complex-probable make up 11.30 % of the assemblage but their use as projectile elements cannot be guaranteed.

Remains of ochre have been found on 15 bladelet fragments (11.30 %) as in the case of denticulated backed bladelet. They are always associated with their hafting system. Together with the study of the fractures, this suggests that the backed bladelets were used as projectile elements and were therefore related to hunting activities.

In addition to the bladelets, 24 flint artefacts from Square XI.B have been examined: four flakes, three small flakes, ten blades, a proximal fragment of a blade, two indeterminate fragments and four burins (a dihedral angled burin and three straight dihedral burins).

Of the flakes, only one of them was used as a wedge. Two flakes displayed no traces and one could not be observed microscopically because of the alterations to its surface.

One of the small flakes does not display use-wear, a thick retouched flake could not be studied because its surface was burnt, possibly because it had fallen into one of the hearths documented in the level (Moure Romanillo, 1975), but one retouched small flake displayed slight traces on an edge produced by scraping hard animal matter.

Two of the blades could not be analysed because of their poor state of conservation. Six blades possessed no traces, whereas the other two displayed use-wear connected with butchery on one of their edges (cutting actions). One of them was involved in cutting an indeterminate relatively hard material (Fig. 10: 2).

The two indeterminate fragments displayed no use-wear of any kind.

Finally, the burins reflect different realities. The angled dihedral burin was used to scrape an antler in an action with a short duration (Fig. 10: 1), while one of the straight dihedral burins was used to cut a groove in antler. The other two straight dihedral burins have no use-wear but one of them was used as a bladelet core.

Of this small assemblage, four tools (16.70 %) show a series of post-depositional traces (patina and soil gloss) that impede microscopic analysis and 13 objects do not display any type of use-wear (54.20 %). Therefore, only seven artefacts were used (29.10 %) in short transversal and longitudinal actions on hard animal matter, like antler and bone, or in butchery tasks.

The use-wear documented in the traceological analysis of the sample is related to activities that involved working mostly with hard animal matter and expeditious actions of short duration. These results, together with those obtained in the study of the bladelets and the absence of complete sequences of the operational chains, support the idea of a short occupation in Sub-level 1c2.

5. Discussion

The use of flint based on a management of materials from of diverse sources, as seen in Tito Bustillo Cave (Fig. 11), is able to confirm the preliminary conclusions reached at other Lower and Middle Magdalenian sites in the same geographic area in Cantabrian Spain, such as Las Caldas – Chamber II (Corchón et al., 2009) and the proximate caves of El Cierro (Álvarez-Fernández et al., 2016) and Cova Rosa (Álvarez-Fernández et al., 2020). In those two cases, the procurement of mainly local resources was complemented by a wide array of other raw materials, generally of much better knapping quality than the local resources and acquired in the Vasco-Cantabrian basin and the Western Pyrenees.

In Sub-level 1c2 at Tito Bustillo Cave flint was the most frequently used raw material in the lithic industry (50.6 %). It should be noted that the quartzite, which is in the course of being studied, with the preliminary results presented here, forms practically all the other half of the lithic assemblage (49.2 %). Since it is assumed that most of the quartzite was procured in the proximate surroundings of the site, this raw material can be added to the few remains of quartz, Piloña flint, Alba radiolarite and Fito chert as the main resources acquired locally. In contrast, the assemblage studied here displays a significant peculiarity since a tracer material, Flysch flint (its nearest outcrops are on the coast of Biscay, about 180 km away in a straight line), which is indeed found at most of the sites studied in northern Spain (Tarriño et al., 2015, 2016), was used more than the other flint types (33.3 %). This type of flint is the main raw material at many Lower Magdalenian sites in the eastern sector of Cantabrian Spain (e.g., Level 17 of the Outer Vestibule or "Cabin" and Level 504 of the Vestibule Rear "Corral" at El Mirón Cave; Level Csn-

Fig. 10. Results of use-wear analysis. Scale bar 2 cm. 1: An angled dihedral burin used to scrape an antler (Original magnification 100x of Optical Microscope) and 2: A blade used to cut a hard material (Original magnification 200x of Optical Microscope).

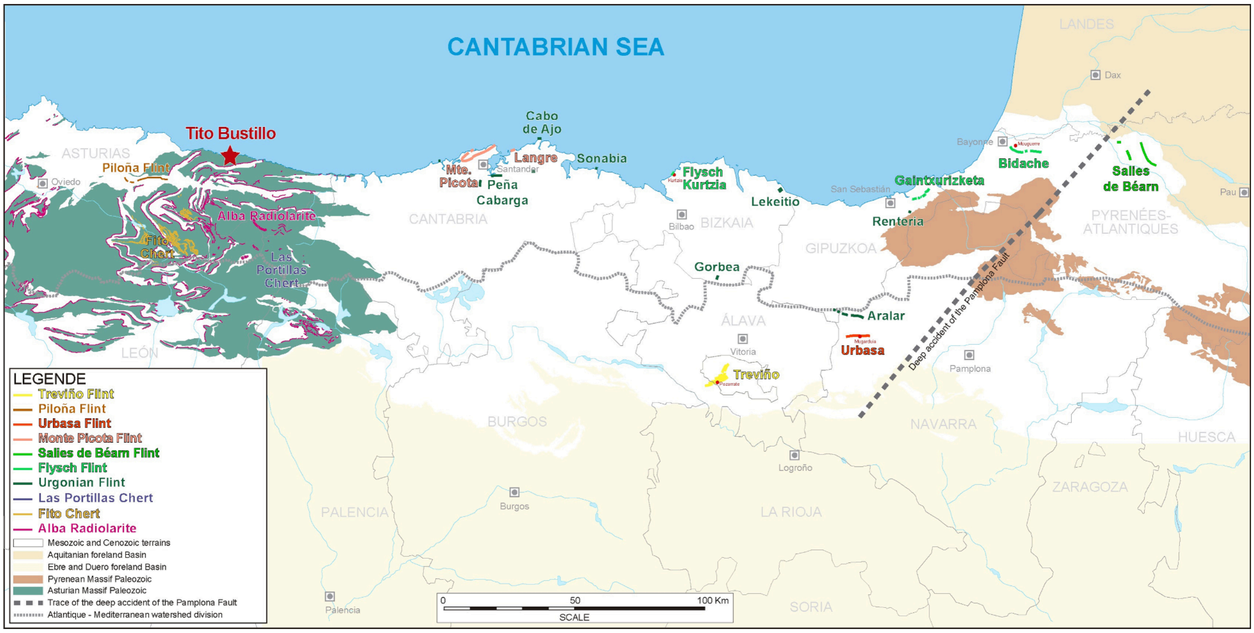

Fig. 11. Provenance of the flint types identified in Sub-level 1c2 at Tito Bustillo.

Camr at Santimamiñe, Level Lgc inf at Antoliñako koba, Level IV at Praileaitz I, and Level F at Urtiaga) because in those cases it was a local or proximate regional resource (Tarriño and Aguirre, 2002; Tarriño, 2011, 2017; Fontes, 2016b; Fontes et al., 2016, 2018).

This strategy for the procurement of the different flint types used by the hunter-gatherers who occupied Tito Bustillo Cave is also observed at the sites of El Linar, Las Aguas and Cualventi, ascribed to the Lower Magdalenian. These sites are in the central sector of Cantabrian Spain and their assemblages are based on local materials (e.g., Monte Picota) together with regional and tracer types mainly from the eastern sector and, in smaller numbers, the northern side of the Pyrenees. Most of those latter types appear in small proportions, except Flysch flint (a distant regional raw material, as the outcrops are about 100 km away from those sites), which makes up nearly half the flint remains found at those three sites (49.1 %) (Tarriño, 2016).

Procurement of quartzite followed a double and complementary strategy consisting of 1) the procurement in specific conglomerate formations of Pennsylvanian Carboniferous (Bastida, 2004) and Tertiary and Cretaceous age, as shown in near areas (Santamaría et al., 2010; Herrero-Alonso et al., 2020; Prieto et al., 2021, 2022) and 2) the selection of quartzites from fluvial deposits in the Sella and probably Cares and Deva valleys, where the aforementioned conglomerates had been eroded. In both cases, the distance from the cave to these procurement contexts is smaller than 30 km. It is important to mention that quartzarenites were only gathered in river deposits, probably in a more expedient behaviour related to embedded procurement than a direct procurement. As already acknowledged in proximate areas (Álvarez-Alonso et al., 2013; Prieto et al., 2021, 2022), intensive selection was required to obtain deformed and especially metamorphic quartzite types. Acquisition from outcrops cannot be discarded. However, the scarce evidence and the preservation state of surfaces force us to nuance the conclusion.

The technological study of flint in Sub-level 1c2 in Tito Bustillo Cave indicates varying patterns in the management of the different flint types and their reduction processes, detected in the degree of completeness of their operational chain. Thus, in the only resource in which all the reduction phases are present (Alba radiolarite; local), products from the maintenance of debitage are abundant (15.1 %) and the percentage of flakes (50.7 %) is higher than that of blades (13.7 %) even though no flake cores have been found. This contrasts with the other resource that appears most frequently (Piloña flint; local), in which the number of shaping products is smaller (1.9 %) and blades (64.9 %) are much better represented than flakes (21.3 %). This flint type therefore displays an incomplete operational chain, like the other types (Monte Picota, regional; Urgonian, regional; Flysch, tracer and Treviño, tracer). Few products from the maintenance of debitage, like flanks and crests, have been detected in those types. This may be the result of good initial preparation of the cores, which reduced the need for maintenance, an indication that the cores reached the site in a quite advanced stage of the preparation process, or the result of a bias owing to the small surface that was worked. In the case of the types with incomplete operational chains (Fito-local, Portillas-regional, Urbasa-tracer, Salies-tracer), the almost exclusive finds of prepared blanks suggests that they arrived already fabricated or as cores shaped away from the site, ready for the occasional removal of blanks.

The preliminary technological characterisation of the quartzites suggests differences in the exploitation system and degree between types of quartzites. In general, orthoquartzites and BQ quartzites follow complex knapping schemes and they were highly retouched. In contrast, quartzarenites were less exploited in more expedient behaviours. Despite this is preliminary research, the high quantity of types and varieties of quartzites, the small quantity of cores and core preparation/rejuvenation products suggest the entrance on the site of multiples raw material units, probably knapped out of the site.

The typological study of the retouched flint artefacts from Tito Bustillo Cave shows the preference for laminar products (83.3 %), compared with flakes (15.2 %), as the blanks to be retouched. This is reflected in the predominance of backed bladelets (55.4 %) and objects with continuous retouch (23.0 %), of which, out of a total of 47 remains, 41 are made on blade blanks. Burins (8.8 %) are much more abundant than endscrapers (1.0 %), which are represented by only two specimens (a simple endscraper and an endscraper-burin). Straight dihedral burins are most common in the burins category, followed by angled burins on a break in second place. No geometric microliths have been found in the assemblage. Flysch and Piloña flint are the two main raw materials used for backed tools (36.5 % and 30.4 %, respectively) and artefacts with continuous retouching (42.6 % and 25.5 %, respectively). Similarly, Flysch flint predominates among the burins (55.6 %).

The preliminary typological characterisation of quartzite artefacts shows differences with the flints', mainly because of the absence of backed tools on the firsts. In contrast, burins in quartzites are more relevant, as sidescrapers, endscrapers and denticulates are. These typological, also technological, differences between quartzites and flints were also proposed in the Cantabrian Spain in similar chronologies and they were referred to the different physical properties of both raw materials, the differential management of resources or even because of the distinct typological visibility (González Sainz, 1991; Straus, 1996; Vaquero and Alonso-Fernández, 2020).

Moure Romanillo (1990) makes a brief study of the composition of the lithic assemblages from the Upper and Lower Complexes in the *Área de Estancia* in Tito Bustillo Cave. Since the present study is restricted exclusively to Sub-level 1c2 and evidence of other raw materials than flint have not been included, the data from the present technological study should be considered in conjunction with those of the previous investigation. In general terms, flint and quartzite were noted as the main raw materials in the lithic assemblage in Level 1, in similar proportions, with a predominance of flakes in quartzite and laminar blanks in flint, and the retouched artefacts were in this latter resource. Nonetheless, it is interesting to note the information about the typological composition, especially the one referring to the Lower Complex (Sub-levels 1c2-4). Tools on microblades, especially backed bladelets, make up over half the assemblage (53.9 %). The total number of burins (11.8 %) is clearly larger than that of endscrapers (4.6 %). Among the former, dihedral burins are the most frequent, followed by burins on a truncation; among the latter, simple endscrapers are more abundant than those on the end of unretouched blades. Geometric microliths are absent. Therefore, in general terms, the present results for Sub-level 1c2 match the previous data, except in the case of burins on a truncation, which are less significant in this study. The specific study of tools in quartzite will probably increase the percentages of burins and endscrapers in the present assemblage to the proportions given above.

The techno-typological pattern determined in both in the present study and J.A. Moure Romanillo's research can also be compared with the situation observed in El Cierro (Level F), a cave in the lower Sella valley about 3 km from Tito Bustillo, but ca. 500 years older (Álvarez-Fernández et al., 2016). Flint is the predominant raw material (70.3 %) and quartzite makes up a little less than a third of the assemblage (28.5 %). Flakes were used more often than blades (41.9 % and 12.9 %, respectively), without any significant differences between the two raw materials. However, retouched tools were mainly shaped in flint (94.3 %). Backed bladelets form the most common typological groups (30.2 %) followed by endscrapers (25.0 %), which are more abundant the burins (10.3 %). Carinated and nucleiform typologies dominate among the former and dihedrals in the latter. The representation of substrate tools is significant (12.9 %), artefacts with continuous retouching are relatively common (5.2 %) but there is no evidence of geometric microliths. The main difference compared with Tito Bustillo Cave is the predominance of flint as the raw material and the lesser use of quartzite, the preference for flakes as blanks, although in the case of retouched artefacts the use of blades is more usual (40.7 %), the large number of carinated and nucleiform endscrapers, which are absent in Tito Bustillo, and the greater importance of substrate tools compared with objects with continuous retouch.

The functional study of a sample of flint tools from Sub-level 1c2 has shown that, in our opinion and as a preliminary conclusion, this sub-level corresponds to a short occupation. The backed elements hardly display any diagnostic traces but can be related to projectile elements fabricated mostly to rearm hunting weapons. Working with hard animal matter like bones and antler has also been documented and may be connected both with the manufacture and repair of the shafts of their weapons and with the butchery of their prey. Working with dry hide has been identified to a lesser degree, probably in connection with the repair of leather objects.

Comparison of the data obtained in the functional study of the lithic assemblage from Tito Bustillo Cave with other sites of the same age is difficult because of the scarcity of this type of study. However, the results are similar to those reached for Level IV in the Cave of Praileaitz I (Clemente-Conte et al., 2017), where the implements were used mainly in activities connected with hunting and the use of hard animal matter.

This occupation model identified for Sub-level 1c2 in Tito Bustillo Cave through its lithic assemblage: a provisional camp for mobile hunter-gatherer groups that made stops to repair their hunting equipment, is similar to the model proposed for sites attributed to the Upper Magdalenian in the northeast of the Iberian Peninsula, such as Cova Alonsé (Domingo, 2013), and Zatoya Cave (Laborda, 2010), and differs from the model suggested for the occupation in Cova del Parco (Calvo, 1997; Calvo et al., 2007–2008) and Molí del Salt (Martínez, 2005), which were sites specialised in the different stages of the operational chain for processing hide.

6. Conclusions

The *Área de Estancia* of Tito Bustillo presents a palimpsest of Magdalenian occupations (Level 1), one of the most important of those documented in SW Europe. In particular, a large set of lithic evidence has been documented in the different sublevels of the site.

Sub-level 1c2 in Tito Bustillo Cave seems to demonstrate above all the high mobility of hunter-gatherer groups who acquired supplies of different raw materials of good quality for making, repairing and rearming their hunting weapons, in the context of a quite specialised and possibly planned occupation that was, however, of short duration.

The full study of the lithic assemblage has combined the characterisation of the raw materials, applied to types of both flint and quartzite, the debitage techniques and patterns, and the determination of the function of the tools through use-wear analysis.

The main conclusions that can be reached through the results of these approaches are: 1) the existence of the circulation of raw materials to satisfy the technological needs of their users, as observed at other Lower and Middle Magdalenian sites along the Cantabrian coast; 2) the high degree of selection of types among the two most abundant groups of rocks in the archaeological record in the region, flint and quartzite; 3) the environmental and geographic diversity in the procurement of these resources; 4) a preference for some specific types, such as Flysch flint, whose nearest outcrops were nearly 200 km away in a straight line, compared with more easily available types of poorer knapping quality; 5) cores reached the site in a more or less advanced stage of shaping-out with a good initial preparation of them, or a marked bias owing to the small surfaces that were worked, are the main explanations for the deficit of preparation and repair products in the reduction processes of most of the lithic types; and 6) a pattern specialising in hunting activities, seen in the large number of backed bladelets used as projectile elements and the functional analysis, which has documented working with hard animal matter also in the context of hunting.

The study of the lithic assemblage from Sub-level 1c2 in the *Área de Estancia* in Tito Bustillo Cave needs to be complemented with the data from the full review of the other archaeological material (osseous industry, archaeozoological evidence, portable art, etc.) in order to establish the specific functionality of the occupation. This will provide new information about the hunter-gatherer groups that inhabited the estuary of the River Sella, and Tito Bustillo Cave in particular, in the late Pleistocene.

CRediT authorship contribution statement

Sergio Martín-Jarque: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Diego Herrero-Alonso:** Investigation, Methodology, Writing – review & editing. **Antonio Tarriño:** Investigation, Methodology, Writing – review & editing. **Cristina López-Tascón:** Investigation, Methodology, Writing – review & editing. **Alejandro Prieto:** Investigation, Methodology, Writing – review & editing. **Julián Bécares:** Investigation, Methodology, Writing – review & editing.

Esteban Álvarez-Fernández: Writing – review & editing.

Declaration of Competing Interest

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

Data availability

Data will be made available on request.

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Appendix A. Supplementary material

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