Flint as raw material in prehistoric times: Cantabrian Mountain and Western Pyrenees data

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Abstract
Currently, investigations about siliceous resources exploited during prehistoric times in the Cantabrian Mountain and Western Pyrenees are still scarce and, generally, they did not employ methods which go deeply into the provenance characteristics.

A review of the studies of lithic resource exploitation offered by historiography indicates that the theme has been examined in a generalized way in most cases. A model with a clear difference between the Eastern and Western territory of the Cantabrian Coast was created: an area with flint and an area without flint. This model needs to be qualified, because in recent years siliceous outcrops have been discovered in zones of the Western Cantabrian Mountains (Asturias). Information from the investigations in the Cantabrian Mountains, Basque-Cantabrian Basin, and Western Pyrenees indicates diverse patterns. There is a preference for lithic raw material found near the occupations, together with the inclusion of exotic or distant flints, always of good quality, to a greater or lesser extent, according to the chronological periods and the geographical location.

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1. Introduction
Prehistoric knappers employed a great variety of lithic materials as raw material. Aside from having an appropriate size, those materials only needed suitable fracture and hardness in order to achieve their technological purposes.

Therefore, among the lithic raw material used in Prehistory, we can find “hard rocks” that embrace the entire petrogenetic spectrum from igneous and metamorphic to sedimentary. The fundamental ones are the siliceous rocks of non-detrital sedimentary origin (commonly named flint), because of their excellent properties for knapping and the wide distribution of outcrops. There can be no doubt that this was the main mineral resource in Prehistoric times in SW Europe.

Flint is of great interest as a lithic raw material, also considering that is a “Traveller rock”. Since the beginning of the prehistoric investigations (mid-XIX century, for example Damour, 1865), the necessity for obtaining information about the provenance and availability of these lithic resources has been recognized. Nevertheless, the difficulty in conducting this type of study has caused the results to be poor. A geocarchaeological cross-functional view is necessary to have valid information about mobility and territoriality. In this way, since the late 1990s, lithic provenance studies were undertaken systematically, focused in the Basque-Cantabrian Basin and in the Western Pyrenean region, broadened to the Cantabrian Mountains, Cenozoic Ebro Depression, and southern Aquitaine Basin.

This paper is a compilation of the investigations about flint availability and exploitation in the territory. The siliceous rocks are described and information of the previous management studies is summarised, in order to develop a classification of the flints from the perspective of the diffusion.

2. Overview of siliceous rocks investigation in the Cantabrian Mountains and Western Pyrenees
The flint availability as a raw material in the Western Pyrenees is an investigation that began to develop systematically in the 1980s in the North-Pyrenean watershed. The studies in 1980–85 were started by the team formed by Chauchat and Normand, and produced many publications (Normand, 1986, 1987), initiating analysis in the Grand Sud-Ouest of France. There were also works about flint in adjacent regions with reference to their geological aspects in north-Aquitaine: Séronie-Vivien and Séronie-Vivien (1987), or to...
the prehistoric provenance in Aquitaine: Demars (1982); Geneste (1985, 1988); Geneste and Rigaud (1989); Morala (1984); Turq (1989), and in Midi-Pyrénées: Simonnet (1981). Those studies culminated in the celebration of the VIIth International Flint Symposium held in Bordeaux (France) in the autumn of 1987 where several contributions were presented and edited by Sérionie-Vivien and Lenoir (1990).

In the North-Pyrenean watershed, investigations continued since the symposium: in Aquitaine (Demars, 1994; Turq, 2000; Sérionie-Vivien, 2003); in Midi-Pyrénées (Chalard et al., 1996; Lacombe, 1999; Simonnet, 1999, 2002; Foucher, 2004); in Cantabria (Fouéré, 1994); in Creuse (Aubry, 1991); in Auvergne (Sermonet et al., 1998); in Languedoc (Briois, 1997; Grégoire, 1998; Bazile, 1999); in the South-Alpine Massif (Bressy, 2003); in Pyrénées-Atlantiques and Landes (Normand, 1993, 2002; Bon et al., 1996; Bon, 2002).

In the South Pyrenean watershed of the Western Pyrenees, research followed a different course. The studies about silicifications had begun in a systematic way in the 1980s, exclusively centred on geological aspects (Elorza and Arriortua, 1985; Elorza et al., 1985; Elorza and Bustillo, 1989; Tarríno et al., 1989; Urtiaga et al., 1990). The pioneer attempt of petrographic characterization of flints in a prehistoric site was carried out by Strauss and Clark (1986) in La Riera cave (Asturias). It was not until the next decade when works based on the application of geological knowledge and methods started to attempt to identify the prehistoric flint provenance. However the results were not very conclusive, including Arias (1990, 1992) also in Asturias; Sarabia (1990a; 1990b), González-Sáinz (1992), Bernaldo de Quirós and Cabrera (1996); Montes-Barquín and Sanguino-González (1994) for Cantabria and Ortiz et al. (1990) and González and Ibáñez (1992) for the southern Basque-Country, Mazo and Cuchí (1992) and Mandado and Tilo (1995) in Aragon, and Terradas et al. (1991), Terradas (1996), and Mangado (2005) in Catalunya.

In the Vth International Flint Symposium held in Madrid and Granada in 1991, the scientific contributions about Cantabrian-Pyrenean flint and adjacent regions were limited and exclusively of geographical character: Elorza and García-Garmilla (1997) and Ortiz et al. (1997), with the exception of a work presented about the presence of non-local flint in the north-Pyrenean watershed (Aquitaine) (Lenoir et al., 1997). The Vth and last International Flint Symposium held in Bochum (Germany) in 1999 did not include any scientific contributions about lithic raw materials in the Cantabrian-Western Pyrenean Region. The end of the 1990s saw important works relating to the provenance of flints used in prehistoric times in the southern Pyrenees. In the Eastern area, in Catalunya, the archaeopetrological studies began to emerge with two PhD thesis (Terradas, 1996). The scheme of flint acquisition that existed in the Cantabrian area previously was that of Sarabia (1999a; 1999b), where local or not very distant management of raw material was accepted. New data provided information indicating the mobility of lithic raw material (Tarríno, 2001a), changing the previous acquisition model. In this new model, it is usual to identify transport of lithic remains tens of kilometres away from the site, in some cases exceeding a hundred and exceptionally two thousand kilometres for the Upper Palaeolithic. The information about flints of the Cantabrian Region now can be compared with that obtained for the identified types in the North-Pyrenean watershed. In 2009, another International Congress in lithic raw materials was held (2nd International Conference of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times). Here were presented for the first time the investigations that have been accomplished about the prehistoric mines of Treviño (Tarríno et al., 2011a, 2011b), Rissetto (2009) presented his PhD thesis about the Magdalenenian in Eastern Cantabria. Subsequently, studies of raw material provenance of emblematic sites were carried out, including Las Caldas (Asturias) (Corchón et al., 2007), Altamira (Cantabria), (Tarríno, 2014), Aitzbitarte IV (Gipuzkoa) (Tarríno, 2011a), Santimamiñe (Bizkaia) (Tarríno, 2011b), Isturitz (Pyrénées-Atlantiques) (Tarríno and Normand, 2002; Elorrieta, in press), and el Sidrón (Asturias) (Sanmartín et al., 2011; Tarríno et al., 2013).

Currently, all the active projects of the University of the Basque-Country (UPV/EHU) have included studies for the characterization of flint types as raw material, and several PhD thesis are in progress. In this way, the acquisition patterns and the use and diffusion of this mineral resource for the Cantabrian-Pyrenean Region were investigated.

3. Petrological approach study of lithic raw materials

3.1. Methods

The lithic remains gathered in the archaeological sites are the only vestiges that can provide information about sourcing areas. However, surveys of this type of material (for our region flint, generally) have been very few.

The study of the lithic raw material questions from a petrologic approach offers the possibility of analyzing flint on three levels (Tarríno and Terradas, 2013):

- **Textural analysis:** allows characterization of the orthochemical (crypto/microcrystalline quartz nature, carbonate relicts, etc.) and allochemical components (fossils, mineral grains, dolomitization, etc.). It is accomplished using microscopy (stereoscopic, petrographic, and scanning electronic microscopes).
- **Mineralogical analysis:** for the characterization of the siliceous minerals presence (quartz ± feldspars ± opal); impurities contents (carbonates ± sulphates ± oxides ± silphides ± clays) using X-Ray Diffraction (XRD); organic matter and water contents are determined by Raman Spectroscopy, Infrared Spectroscopy and Thermogravimetric Analysis (TGA).
- **Geochemical Analysis:** allows the characterization of the geochemical fingerprint of flint regarding its majority and minority components using X-Ray Fluorescence (XRF); trace and Rare Earth elements are determined using Inductively Coupled Plasma Spectroscopy (ICP-MS/OES).

3.2. Objectives of the petrological study

By giving the petrological perspective to the investigations, we can contemplate the geological characterization and the geological/archaeological implications related to the diffusion and the management of the prehistoric lithic industries (Tarríno, 2006a).

The main proposed objectives are:

1. Cataloguing the silicifications capable of being employed as raw material;
2. Petrological, mineralogical and geochemical characterization of the geological flints and their host rock, using the techniques described above;
3. Establishing discriminating criteria between different types of flint by carrying out analyses of the lithic remains collected in archaeological sites;
4. Detecting the points of supply (quarries) of such mineral resources and the geological-geomorphological determining factors that have allowed their exploitation (similar to what would be involved in conventional work of mineral sites);
5. Identifying which of the listed flint was used as raw material in the lithic industries of the archaeological sites; and
6. Investigation of the production strategies and the management dynamics of the prehistoric societies during the late Pleistocene and the Holocene.

Nevertheless, when dealing with this question from a unique archaeological perspective, it is normal not to take into account the first three goals and to go on with the fourth, in the best case, or directly go to the fifth point in order to try to identify the archaeological flint. This methodological partiality prevents these studies from being reliable and comparable to different sites. Finally, the last of the objectives allows us to propose a socio-economic reconstruction of prehistoric societies through the information about flint management.

For the Western Pyrenees, this research has practically started from zero when characterizing the flint used in prehistoric times, aspects in which France and the rest of Europe have been working on for several decades. They have also detected countless prehistoric mining evidences, and identified several flint types that have been employed in Prehistory.

4. Geographical and geological situation

The geographic area where our researches are framed is delimited by the regional extent of the flint outcrops employed by the Prehistoric societies, inside the Cantabrian Mountains (CM); Oviedo Basin (OB); Basque-Cantabrian Basin (BCB); and the Navarre Pyrenees (NP) (Fig. 1), located in the north of the Iberian Peninsula. The Atlantic–Mediterranean watershed crosses it from east to west in a central position separating the northern (Bay of Biscay) and southern limits (South-Pyrenean Thrust).

The geological BCB was the main supplier of flint in the northern Iberian Peninsula, as a necessary lithic resource to satisfy the technological requirement of the prehistoric societies. It is a “small” sedimentary basin, which is composed of Mesozoic and Cenozoic sediments, 15,000 m thick (Lotze, 1960; Ramírez del Pozo, 1971). Its length, between Asturian Paleozoic Massifs and Pyrenean Massifs, is 200 km, while its modal width between the South-Pyrenean thrust and the Cantabrian Sea is around 80 km (Fig. 1).

The presence of sedimentary series in this region has led to the existence of many and varied geological formations with significant silicifications. In the sedimentary record flints are found in almost all the sediments from the Paleozoic to the Cenozoic (Paleogene and Neogene). The sedimentary environments vary from oceanic basin to continental basin (lacustrine-palustrine). Table 1 shows a list of the silicification families organized by the depositional sedimentary environment and geological age.

<table>
<thead>
<tr>
<th>Silicification groups</th>
<th>Geological age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Pelagic Flint</td>
<td>Paleozoic-Paleogene</td>
</tr>
<tr>
<td>2 Flysch Flint</td>
<td>Cretaceous-Paleogene</td>
</tr>
<tr>
<td>3 External Marine Platform Flint</td>
<td>Paleozoic-paleogene</td>
</tr>
<tr>
<td>4 Recifal Platform Flint (Urgonian Flint)</td>
<td>Lower Cretaceous</td>
</tr>
<tr>
<td>5 Internal Marine Platform Flint</td>
<td>Upper Cretaceous-Paleogene</td>
</tr>
<tr>
<td>6 Continental Flint (Palustrine-Lacustrine)</td>
<td>Paleogene-Neogene</td>
</tr>
</tbody>
</table>

Each of these sedimentary environments normally has several types of flint (Tarrío, 2006a). Totalling the geological formations with flint exposed in the Cantabrian-Western Pyrenean Region, there are fifteen different units with flint with at least fifty varieties and countless outcrops.

The fact that there are so many types of silicifications exposed does not mean that all have been used in prehistoric times. Of these types, only a few have been used with the intensity that prehistoric groups needed. The style of exposure must be observed: if the flints are included in the host rocks more or less covered, with better or worse accessibility, with different distribution, and with hard or weak host rocks. The siliceous rocks that appear in blocks or nodules were easily extracted or collected. Generally, there are outcrops/workshops in which flints have been extracted, selected and accumulated by external geodynamic processes in superficial and secondary formations. Hence, geomorphologic research is important for studies of raw materials in Prehistory.

5. Flint in the Cantabrian Mountains and Western Pyrenees

The compilation of siliceous rocks in the Cantabrian Mountains and Western Pyrenees is presented below, grouped according to the formation environment and the geological age of the flints. Fig. 2 shows the main outcrops. The terms flint and chert are distinguished in this paper; flint is the common name, and chert a specific variety of siliceous rock with particular characteristics.

5.1. Carboniferous Black Cherts and Lidites from the Cantabrian

This is a set of black flint and/or lidites that crop out in the Cantabrian Mountains, that are strongly fissured and with an aptitude for knapping that is, in general mediocre. This is why they were seldom employed in the archaeological sites of the area. Various Carboniferous geological formations containing these cherts in the Cantabrian Mountains have been described (Martínez-García, 1981; Barba et al., 1991). They have a wide geographic distribution (Fig. 2).

5.1.1. Vegamión formation chert

These are black cherts included in dark shales and lutites formed in a marine platform with anoxic conditions. They contain nodules of phosphate, lidites and pyrite. The age varies from the latest Tournaisian to the Viséan (Lower Carboniferous).

5.1.2. Barcaliente formation chert

These are black cherts included in very dark limestones, with a fetid odour. They have been formed in marine carbonate platform sediments, with limited fossil content, of Namurian age (Middle Carboniferous).

5.1.3. Lois-Ciguera formation chert

They are black cherts that appear in nodules in the lower part of the Bachende Member, formed by marls and calcareous lutites with strata of bioclastic limestones. This formation originated in a marine environment and contains marine algae, echinoderms, bryozoans, and corals. The age of the formation is Bashkiriense (Lower Carboniferous).

5.1.4. Ricacabiello formation chert

They are black cherts included in a formation of lutites and limestones with ferruginous and manganese nodules. It is formed
with contributions of terrigenous fine materials in the distal zones of the platforms. The age of the formation is Bashkirian (Lower Carboniferous).

5.1.5. “Calizas de Montaña” Flint

They are flints of dark colours (black-grey) included in the wide formation of the “Calizas de Montaña” that outcrops in the Cantabrian Mountains. The flint is found in the highest part of the formation and in the “banded member”, with alternation of banks of black limestones, fine-grained and fetid (Marquínez, 1978; Martínez-García, 1981; Barba et al., 1991). It appears with a high quantity of fauna that permits dating the formation to Westphalian (Lower Carboniferous). Recently, two varieties have been differentiated in this group (Arias Cabal et al., 2009). Its prehistoric exploitation is limited.

5.1.6. Pendueles chert

In Vidiago beach (Pendueles, Asturias), this outcrop is defined as a turbiditic succession in which basal flint layers outcrop (IGME, 1981). It is white and dark banded, very deformed with a thickness of about 40 m (Martínez-García et al., 1971). Its aptitude for knapping is, generally, mediocre and the only confirmed archaeological evidence until today dates from the Neolithic-Chalcolithic (Arias, 1990; Arias et al., 2009). The outcrop is marked in Fig. 2.

5.1.7. Radiolarite

These are siliceous rocks, fine-grained and smooth texture, formed by radiolarians. They appear in layers and ellipsoidal nodules in the rose-colored limestones of “Griotte” type of the Alba Formation, with Lidite strata (IGME, 1981). The characteristic colour is maroon, of opaque appearance, with two main varieties, reddish and greenish. The age dates from the Lower Carboniferous (Upper Tournaisian-Visean) (Martínez-García, 1981). Their outcrops have also a vast geographic distribution (Fig. 2).

Of all the siliceous Paleozoic rocks of the Cantabrian Region, the radiolarites constitute the most exploited flints during the Middle and Upper Palaeolithic in Asturias. In general, this raw material was used more frequently in the Paleolithic sites of eastern Asturias: as Llonín, Cueto de la Mina, La Riera, and Los Canes (Santamaría et al., 2011).

5.2. Jurassic Marine Platform Flint

The Jurassic system is fundamentally represented by sedimentary formations of a carbonate marine platform environment. They are the oldest BCB flints. They usually appear in the Bajocian
(middle Jurassic, Dogger) although they are cited in the Bathonian (Villalobos and Ramírez del Pozo, 1971) and at the bottom of the Malm (Ramírez del Pozo, 1971).

They are homogeneous silicifications which are fractured as a result of the tectonic processes suffered during its geological history. This fragmentation prevents obtaining usable blocks and, therefore this type of flint has not been detected in any of the archaeological sites.

5.3. Lower Cretaceous Recifal Platforms Flint; Urgonian Flint

We find these silicifications in the Recifal carbonate Platforms of the Urgonian Complex of the lower Cretaceous (Aptian-Albian) (Figs. 3 and 4). Except for some isolated cases, the presence of these flints does not have a significant representation in the geological record. Taking into account that each carbonate urgonian platform can have between one and three units with silicifications, and that in the Basin there are 11 main carbonate urgonian platforms, more than twenty could be catalogued. They are flints which have been used occasionally as raw material in Prehistory (Tarrío, 2006a). They have two different origins, silicifications of diagenetic origin and hydrothermal silicifications associated with mineralization (Aranburu, 1998), and their outcrops have a vast geographical distribution (Fig. 2).

5.4. Pyrenean Flysch Flint

This designation includes turbidite geological formations deposited in deep environments (Marine Basin Slope). Those from the Upper Cretaceous have ages from the Cenomanian to the Campanian. The host rocks are composed of bioclastic calcarenites alternating with fragments of molluscs and sponge spicules. Peltoloides, planktonic foraminifera, detrital quartz and heavy minerals can be distinguished. They often have parallel and wavy laminations characteristic of turbidites in primary position (Fig. 5).

The most important ones appear in the Upper Cretaceous outcrops both north and south of the Pyrenees. They are also outcrops in the Paleocene of the Navarre Pyrenees. Distinguishing the different varieties is difficult. The main varieties of the Flysch flint detected in the archaeological sites are listed below.

5.4.1. Kurtzia Flysch Flint

This has been described by Tarrío (2006a,b): in the surroundings of Barrika (Bizkaia) a megabreccia of about 40 m width that comprises a block chaos (megabreccias or olistostrome) (Fig. 2) included in the Elbar Formation, Flysch (Cenomanian-Santonian, Upper Cretaceous) intersecting the coastline in the cliff (Figs. 6 and 7). Erosion detached the flint fragments that are included in a marine-argillaceous matrix and the blocks can be easily collected. Evidence of strong marine abrasion is common in the external zones of the pebbles. Near the outcrops in the coastal plateau, between Punta Galea and the Bay of Plentzia, a set of open-air archaeological sites/workshops generated by works of acquisition and use of this resource are located, since the Mousterian. Barandiarán et al. (1960) called them the “Prehistoric station of Kurtzia”. There are other similar megabreccias in the area between these outcrops and Urizar, west of Gorliz (Bizkaia). These flints are present in almost all the paleolithic sites analyzed in the Western Pyrenees Region, including Antoliñako Koba (Bizkaia) (Tarrío and Aguirre, 2002), Aitzbitarte (Gipuzkoa) (Tarrío, 2011a,b), Anetzagaina (Gipuzkoa) (Arrizabalaga et al., 2014), Alkerdi (Navarre) (Tarrío and Elorrieta, 2012), Las Caldas (Asturias) (Corchón et al., 2007) and Altamira (Cantabria) (Tarrío et al., 2013a) and many others.

5.4.2. Gaintxurizketa Flysch Flint

In the corridor of Deba-Irún in the vicinity of Gaintxurizketa (Gipuzkoa) there are also brecciated formations with abundant flint (Campanian, Upper Cretaceous) (Fig. 2). Tarrío and Mujika (2003) identified the outcrops and the possible existence of associated
workshops. In this case, the megaturbidites are associated with calcareous/limestone Flysch. Evidence of this variety is found in numerous archaeological sites of regional scope, such as Aitzbitarte (Gipuzkoa) (Tarríño, 2011a,b), Ametzagaina (Gipuzkoa) (Arrizabalaga et al., 2014) and Alkerdi (Navarre) (Tarríño and Elorrieta, 2012). The provenance study of the site of Ametzagaina (Gipuzkoa), located in the outcrop, revealed the exploitation of Gaintxurizketa flint (Arrizabalaga et al., 2014).

5.4.3. Bidache Flysch Flint

This is a variety of Flysch flint (Campanian, Upper Cretaceous) exposed between the coast (Biarritz area) and Bidache (Pyrenees-Atlantiques). An important outcrop/workshop of flint is located in Mouguerre near Bayonne (France), and the flint has been described by Normand (2002). On these outcrops, important flint workshops have been recognized with timelines from Ancient Palaeolithic to recent Prehistory. One of its outstanding features is that the parallel turbiditic laminations are usually very evident when patinated. In these formations there are also other important flint outcrops/workshops, including Senix, Pavillon Royal and Chabiague on the coast, and Côte 151, between Behobia and Bidache (Fig. 2). It is the main flint type identified in the archaeological site of Isturitz (Tarríño and Normand, 2002; Elorrieta, in press) and is also relevant in prehistoric sites of Western Pyrenees such as Antoliñako Kòba (Bizkaia) (Tarríño and Aguirre, 2002), Aitzbitarte (Gipuzkoa) (Tarríño, 2011), Ametzagaina (Gipuzkoa) (Arrizabalaga et al., 2014), Alkerdi (Navarre) (Tarríño and Elorrieta, 2012), Las Caldas (Asturias) (Corchón et al., 2007) and Altamira (Cantabria) (Tarríño et al., 2013a). The proximity to the outcrops of other Palaeolithic sites such as Le Baste (Chauchat, 1968; Chauchat and Thibault, 1968) and Arancou suggests that their lithic industries have been supplied with these materials.

5.4.4. Montgaillard-Hibarrette Flysch Flint

These outcrops are located in secondary sites of “Pudingues de Palassou” with eroding limestone of the Flysch (Turonian-Santonian, Upper Cretaceous) with flint near Tarbes (Hautes-Pyrénées, France). Their primary outcrops have been identified in Montgaillard, and the workshops where this flint was exploited in Hibarrette (Barragué et al., 2001; Foucher et al., 2002).

5.4.5. Artxilondo Flysch Flint

Its primary outcrops (Thanetian, Paleocene) are located in the north of the reservoir of Irabia in the forest of Irati between Navarre and Pyrenees-Atlantiques (Fig. 2). It has been described by Tarríño (2006a,b), and although prehistoric workshops have not been
discovered, it was the fundamental flint employed in the Aizpea site in Navarre (Tarrío, 2006a).

5.5. Upper Cretaceous marine carbonate platform Flint

5.5.1. Chalosse Flint

This bioclastic flint is formed in Upper Cretaceous carbonate platforms. It crops out in the area of the Audignon-Montaut anticline and in the edges of the Diapir of Bastennes-Gaujacq (southern Landes) (Fig. 2). It usually is translucent with colour ranging from blackish to greyish. When patinated, flints acquire white-yellowish colours, zoned in many cases. The flint is fine-grained with abundant bioclastic inclusions emphasizing bryozoans and macroforaminiferous (Lepidorbitoides). The bioclastic composition is more perceptible in the flint of the area of Audignon-Montaut (Fig. 8). It has been described by Bon et al. (1996). It is difficult to find primary outcrops where the flint was included in its host rock (Fig. 9). Surveys conducted in the summer of 2003 with the team of F. Bon recognized flint which comes from Maastrichtian (Upper Cretaceous) outcrops (Chalard et al., 2010). It is the principal raw material in the site of Brassempouy (Bon, 2002). Numerous flint prehistoric workshops/outcrops where this siliceous material was exploited are known (Bon et al., 2002). Usually they appear included in the alterites that cover the little depressions at the foot of the small topographic relief originated from the limestones that include silicifications. This flint has also been identified in Palaeolithic sites in the southern Pyrenees such as Antoliñako Koba (Bizkaia) (Tarrío and Aguirre, 2002), Aitzbitarte (Gipuzkoa) (Tarrío, 2011), Ametzagaina (Gipuzkoa) (Arrizabalaga et al., 2014), Alkerdi (Navarre) (Tarrío and Elorrieta, 2012), Las Càldas (Asturias) (Corchón et al., 2007) and Altamira (Cantabria) (Tarrío et al., 2013a).

5.5.2. Ribera Alta Flint

The bioclastic limestones of Ribera Alta Formation (Álava) and Cueva Formation (Burgos) presents silicifications inside the set of carbonate platforms of the Upper Cretaceous in the Navarre Cantabrian Domain (Amiot, 1982) (Fig. 2). The unit is composed of thin massive bioclastic limestones (pelbiosparites), bluish gray, of the Lower Coniacian (Upper Cretaceous) including incipient dolomitization. They are massive limestones of about 120 and 150 m thick where the silicifications crop out (Fig. 10). The following morphologies can be observed (Tarrío, 2006a):

- Botryoidal nodules of sizes of about 10 cm, bluish gray (Fig. 11).
- Nodules with liesegang rings, ovoid or circular. The presence of these “cerebroid rings” makes the flints very easy to differentiate macroscopically (Fig. 10). It is the only type that has been recognized in archaeological sites of the Middle Palaeolithic generally.
- Large, strongly altered nodules with light colours and ellipsoidal morphologies. Their sizes can range from 20 cm to 50 cm. They were rarely employed because of the alteration.

5.5.3. Molino de Oteo Flint

Discrete silicifications occasionally shown as nodules included in the calcareous limestones (arenaceous calcarenites) of Santonian age (ICME, 1978; Tarrío, 2006a). They outcrop near the village of Oteo (Álava) (Fig. 2). No evidence of the use of this flint is found in prehistoric sites.

5.5.4. Fuente de Kristaran Flint

This dark bluish grey flint is included in the arenaceous calcarenites with Lacazinas, of Santonian-Campanian age (ICME, 1979; Tarrío, 2006a). Their outcrops are located near the village of Loza (Álava) (Fig. 2). The data collected shows that this flint was not exploited during prehistoric times.
5.5.5. Infiesto Flint

This flint appears in the Campanian (Upper Cretaceous) massive sandy limestones of the Oviedo Formation (Bernárdez, 1994), with nodular flints and miliolids (Lacazina) appearing near the Infiesto (Asturias) (Fig. 2). They seem to be primary flints that, once rese-dimented in the Oligocene conglomerates of the Oviedo Basin, formed the Pilona flints (Tarríno et al., 2013b). Evidence of prehistoric exploitation has not been identified.

5.6. Upper Cretaceous Pelagic Flint

5.6.1. Salies de Béarn Flint

They are flints that outcrop in the northern Pyrenees in the region of Béarn (Pyrénées-Atlantiques) (Fig. 2). They appear as irregular nodules with abundant bioturbations rich in carbonate relicts, giving them a zoned appearance. It is common to find planktonic foraminifera (usually globotruncanids) that reveal that their depositional environment was a deep marine basin. It has been described by Normand (2002). The shortage of outcrops has not allowed the location of the host rocks of the silicifications. Plotting the workshops on the geological map (1: 50,000 scale) indicates that the host rocks correspond to a wide Campanian carbonate series exposed in the anticline of Peyrehorade near Orthez (Pyrénées-Atlantiques).

It is usual to find it in the north Pyrenean archaeological sites such as Isturitz (Tarríno and Normand, 2002; Elorrieta, in press), and it has been identified in some Palaeolithic sites in the southern Pyrenees: Antolínako Koba (Bizkaia) (Tarríno and Aguirre, 2002), Aitzbitarte (Gipuzkoa) (Tarríno, 2011a), Santimamiñe (Bizkaia) (Tarríno, 2011b), Ametzagaina (Gipuzkoa) (Arrizabalaga et al., 2014), Alkerdi (Navarre) (Tarríno and Elorrieta, 2012), and Altamira (Cantabria) (Tarríno et al., 2013a). The prehistoric workshops that exploited this type of flint are abundant in the region of Béarn.

5.6.2. Tercis Flint

This type of flint has been defined thanks to the information from the prehistoric workshops located in the vicinity of the Grand-Carrière or Carrière d’Avezac (Fig. 12) in the village of Tercis-les-Bains near Dax (South Landes) (Fig. 2). The quarry has been used as a GSSP (Global boundary Stratotype Section and Point). In the section exposed in the quarry (310 m thick), the silicifications can be observed (Fig. 13). Odin (2001) divided the outcrop into five units from lower to upper: 1) Lacave, 2) Hontarède, 3) D’Avezac, 4) Les Vignes, and 5) Bédart.

Flints appear in the Hontarède unit (base) and in Les Vignes unit (top). Hontarède includes dark flint nodules distributed in beds through the whole unit, about 15 m thick, of Campanian age. Les Vignes is much thicker, about 100 m, with two types of flint: a gray flint that appears in the lowest 30 m, and dark flint nodules in the upper 70 m. The Campanian-Maastrichtian boundary is in the area of the clear flints, so these flints can be of either age. The dark flints of this unit are Maastrichtian.

They are quite translucent, dark flints, and can have small planktonic and benthic foraminifera (0.1–0.5 mm). Flints are described by Normand (2001, 2002). In the surroundings of the outcrop are prehistoric workshops such as Les Vignes (Normand, 1984). It is common to find this flint in prehistoric sites of the north-Pyrenean area. This flint has been detected in the sites of Antolínako Koba (Bizkaia) (Tarríno et al., 1998; Tarríno and Aguirre, 2002) and in Mugarduia (Navarre) (Tarríno, 2013) kilometres away from the outcrop.

5.7. Paleocene carbonate marine Platforms Flint

5.7.1. Urbasa Flint

They are flints exposed in the karst of the Sierra of Urbasa (Navarre) (Figs. 2 and 14). They are silicifications located in the depositional sequence SD-6 defined by Baceta (1996). They have...
been dated to the Middle Thanetian (Paleocene) by foraminifera (Fig. 15): discocyclina (D. seunesi) and nummulites (N. heberti). Urbasa flints were formed in external marine platform environments. Macroforaminifera, as well as many remains of echinoderms and a very characteristic incipient microdolomitization, appear (Tarríno et al., 2007). Silifications are presented in nodular morphologies. These primary flint outcrops were unknown until our investigations (Tarríno and Aguirre, 1997; Tarríno, 2001a,b).

The karstification suffered by the carbonate formation host rock is responsible for the use during Prehistory of those silifications. The meteoric action dissolves the limestones and frees the flint nodules that accumulate in the depression zones and bottoms of dolines (Knauth, 1994) and that could be easily acquired by prehistoric people.

It is a silification that has been intensely exploited in Prehistoric times. In the area of the Sierra of Urbasa, much archaeological evidence has been found associated to the lower Palaeolithic, as Aranzaduia (Barandiarán and Vallespí, 1984), to the Upper Palaeolithic, as Urb.11 (Cava, 1986, 1988) or Portugain (Cava and Barandiarán, 2008), the important flint workshop of Mugardúa Sur (Barandiarán et al., 2013; Tarríno, 2013) or the numerous megalithic monuments of the last periods of Prehistory (Barandiarán and Vegas, 1990).

Urbasa flint is one of the main flints that prehistoric groups exploited in the Cantabrian Mountains and in the Western Pyrenees. It is one of the “lithic tracers” of the Cantabrian and Western Pyrenean Region. The transport of Urbasa flint westward over distances that can exceed 300 km is noted at Las Caldas (Asturias) (Corchón et al., 2007), or over 150 km northeastward, as at Isturitz (Pyrénées-Atlantiques). Distribution covered a vast territory including the Cantabrian Coast (Tarríno et al., 2013a), Antoliñako Koba (Bizkaia) (Tarríno and Aguirre, 2002), Aitzbitarte (Gipuzkoa) (Tarríno, 2011), Ametzagaina (Gipuzkoa) (Arrizabalaga et al., 2014), the Western Pyrenees (Tarríno, 2006a) (Tarríno and Elorrieta, 2012) and also the southern Aquitain Basin (Tarríno and Normand, 2002) or most distant sites such as Las Caldas (Asturias) (Corchón et al., 2007) and Altamira (Cantabria) (Tarríno et al., 2013a).

5.7.2. Loza Flint

These flints belong to the calcareous-dolomitics geological formation inside the Paleogene (Upper Thanetian – Lower Ilerdian). The outcrops are found along the reliefs of Loza-Moraza-Tobera (northern Sierra of Cantabria, Álava) (Fig. 2). Tarríno (2006a,b) described these outcrops as generally stratiform silcretes, slightly dolomitized and sometimes fractured. Their formation environments correspond to platforms that could vary between shallow marine and continentals. Although being relatively varied flints, they are included in the same group, considering that all represent restricted environments (chalcedonitic flint and presence of pseudomorphs of gypsum). In other cases, incipient dolimitization on a chalcedonitic matrix is characteristic. Loza flint appears as a raw material in many Palaeolithic and Neolithic sites of the Basque-Cantabrian Basin, including Mendandia (Tarríno, 2006b) and Kanpanoste (Tarríno, 2006a).

5.7.3. Monte Picota Flint

These flints are equivalent to the Loza, but they are formed in the Maastrichtian and appear in the San Roman syncline, near Monte Picota (Cantabria) in the vicinity of Santander (Fig. 16). They are local flints, mainly employed in the lithic industry of Altamira (Tarríno et al., 2013a) and Cobrante (Tarríno, 2009).

Loza and Monte Picota are flints that were not regularly employed in prehistoric times, because of the poor quality for knapping. Occasionally they can be observed in nodular morphologies (Fig. 17).

5.8. Paleogene conglomerate Flint

5.8.1. Piloña Flint

They are flints that have formed in continental environments of the Oviedo Basin (Oviedo, Asturias) (Fig. 2), in the conglomerate of

Fig. 20. 3D Model of “Sierra de Araico” with the line of the nodular flint layer exploited in the Prehistory. In the box is marked the place where there are half-moon dumps.
the “Pudinga de Posada” (Fig. 18), dated from Eocene-Oligocene (Alonso-Gavilán et al., 2004). The flint pebbles are concentrated along the contact with the Upper Cretaceous. In the conglomerates the flint appears included as pebbles (Fig. 19), presumably derived from the fossiliferous calcarenite (Santonian). The greatest concentration of flint is between Tresali (Nava) and Miyares (Piloña).

It is a micro-cryptocrystalline flint with occasional cementations of megaquartz and chalcedony (fibrous silica). The bioclastic content is characterized by the sporadic presence of macroforaminifera (Lacazinas), miliolides, bryozoans, molluscs, and calcareous algae (Tariño et al., 2013).

This flint has been detected in the Asturias sites: Sidrón Cave, La Viña and Llonín (Tariño and Mujika, 2003) and Las Caldas (Corchón et al., 2007). Recently, it has been recognized in Cantabrian sites, and in archaeological sites of the Basque-Country.

5.9. Cenozoic Lacustrine-Palustrine Flint

5.9.1. Piedramuelle Flint

These flints are located in Cenozoic carbonates, of palustrine-lacustrine origin, in Piedramuelle (southeast of Oviedo) (Fig. 2). The Cenozoic is represented in this area by very small isolated outcrops less than 1 km² (Truyols et al., 1991).

They are flints formed in carbonate continental environments of the Oviedo Basin (Asturias). They are massive silcrete silicifications above the whitish brecciated limestone. They are exposed along the western boundary of the Basin in small outcrops that are discordantly situated above the Paleocene, in the village of Piedramuelle and in the territories occupied by the city of Oviedo. It has been used as local raw material in nearby sites such as Las Caldas (Corchón et al., 2007).

5.9.2. Treviño Flint

Treviño flints occur in Miocene terrains (Aquitanian, Continental Cenozoic) of the Miranda-Treviño Depression (South of Álava – North of Burgos) (Fig. 2). Their more accessible outcrops are in the reliefs generated by the Sierra of Araico (Berantevilla-Treviño, Álava-Burgos) and its extension to the north of the Sierra of Cucho-Busto (Treviño, Burgos) (Fig. 20). They are flints formed in lacustrine-palustrine environments, with compact limestones and dolomites, dolomitic limestones, and calcareous dolomites. The fossils of continental environments predominate (gastropods, ostracodes, etc.) (Fig. 21). Silcretes (siliceous crust of stratiform morphologies) are the most common silicifications (Fig. 22). Four siliceous microfacies have been differentiated (Tariño, 2006a):

- Nodular flints with bioclasts. They usually have liesegang rings.
- Clotted silcretes with fenestral porosity, in stratiform disposition.
- Brecciated silcretes with footprints of roots and porosity with vadose cementations, in stratiform disposition.
- Banded micrites with algae lamination and occasionally ostracodes.
A high number of hammerstones (ophite) and flint mining exploitation structures have been discovered, in trenches and dumps (Fig. 23) (Tarríno, 2004; Tarríno et al., 2011; Benito-Calvo et al., 2010). Recently, these flint mines have been dated to the Neolithic (Tarríno et al., 2011, 2014).

In almost all the archaeological sites of the Cantabrian Mountains and Western Pyrenees that have been studied these flints have been identified, for example in the Pleistocene sites: Antoliniako Koba (Gauteguiz-Arteaga, Bizkaia) (Tarríno, 2001a,b), Bolinkoba (Bizkaia) (Tarríno and Aguirre, 1997), Urratzka-III (Bizkaia) (Tarríno, 1997); Labeko Koba (Gipuzkoa) (Tarríno, 2000), Izturtz (Pyrenées-Atlantiques) (Tarríno and Normad, 2002), Portuguan (Navarre) (Tarríno, 2008), Mugardu (Navarra) (Tarríno, 2013), El Linar, Las Aguas, Cualventi, Altamira (Cantabria) (2013), El Linar, Las Aguas, Cualventi, Altamira (Cantabria) (Tarríno, in press) and Las Caldas (Asturias) (Cortés-Atlantiques) (Corchón et al., 2006) and in Holocene sites: Mendandia (Treviño), Tarríno (2006b); Kanpanoste Goikoa and Atxoste (Alava) (Tarríno, 1998), and Las Yurdinas-II (Alava) (Tarríno, 2003).

Its diffusion, similarly to Urbasa flint, Fyrsich flint and Chalosse flint, reaches emblematic sites. It is one of the most important tracer flints in the Cantabrian and Western Pyrenean Region.

6. Classification of flints from the management perspective

In order to classify lithic industries from the management perspective, the first step is petrological study. Interrelation of petrology with the different analysis structures proposed by the Analytic Typology (Laplace, 1973; Fernández-Eraso and García-Rojas, 2013): modal-modal-morphological (retouching mode), the technical (how the artefacts are configured) and the typometrical (linked to sizes and proportions) allows understanding of the management dynamic for the raw material. Relating the management and diffusion allows understanding the lithic industries’ socio-economic values (Fig. 24).

With the available data and accordance with the flint utilization in prehistoric times, we propose a classification from the point of view of the diffusion in relation to the production and the use in the site.

- **Local flint:** its use can be substantial (more than 90%) or major, representing more than half of the lithic industry, if it has good knapping quality. Generally, it is transported a maximum distance of around 20–30 km from the outcrops. Sometimes there are outcrops near the site but they are not exploited regularly or substantially, because they are bad quality. In local flint production, all the stages of the *chaîne opératoire* are represented.

- **Regional flint:** is not representative in the site. It can be carried a distance of 30–60 km and exceptionally 120 km from the outcrops. They are flints with a discrete quality napping. The lithic remains in regional raw material generally correspond to intermediate and later stages of the production sequence. This flint covers a relatively large area.

- **Tracer flint:** These are the ones that define the territories because of their quality and diffusion. They appear in low percentages in the lithic industries and in exceptional elements, as retouched artefacts. This flint can travel a distance of 60–120 km, exceptionally exceeding 200 km. They are flints of good and very good quality for knapping. There is another category that should be included in this group; the Super-Tracer flint: exceptional for its very good quality for knapping and must be available as large exploitable blocks. Apart from defining the territories as the tracer flints, they are the most employed for making highly regarded lithic objects, such as “Great Blades”, Halberds, etc.

7. Conclusions

The Basque-Cantabrian Basin was a fundamental flint supply region. Flint is a necessary lithic resource satisfying technological requirements of the prehistoric societies of the northern Iberian Peninsula. With the expanded data in the previous sections, from the six “Groups” of geological formation that host the silicifications of the Cantabrian Mountains-Western Pyrenees it has been possible to define at least 14 Classes of flint that have been employed by the prehistoric people to a greater or lesser extent (Table 2).

Table 2
<table>
<thead>
<tr>
<th>Flint group</th>
<th>Flint age/Family</th>
<th>Flint type</th>
<th>Diffusion model</th>
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<tr>
<td>Pelagic Flint</td>
<td>Carboniferous “Black Cherts”</td>
<td>Vegamin Formation Chert</td>
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<td></td>
<td>Barcaliente Formation Chert</td>
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<td>Monte Picota Flint</td>
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(continued on next page)
From these 14 classes, at least 30 flint types can be defined, associated to a huge number of outcrops distributed along the Cantabrian and Western Pyrenean Region. The number may increase with future investigations. The characterization of all of them from a petrological approach is basic work that should be done in order to understand the management of this important mineral resource in Prehistory.

For the Cantabrian and Western Pyrenean Region, there are four Tracer Flints: three South-Pyrenean, in the Basque-Cantabrian Basin (Flysch Flint, Urbasa Flint and Treviño Flint) and the other North-Pyrenean, in the southern Aquitaine Basin (Chalosse Flint). Since the Neolithic a new Super-tracer flint variety entered the region, the Ebro Evaporitic Flint. These outcrops and workshops are located out of our territory, in the Depression of the Ebro River (the nearest outcrops/workshops in Ablitas, Navarre) and in the Intra-Iberian Basin of Calatayud-Teruel, in the Jiloca River Valley, tributary of the Ebro where the main outcrops/workshops are found (Royo et al., 2009). By application of this recent and novel methodology and investigation, as long as more precise information is obtained about the geological formation that contains the silicifications, it could be possible to continue specifying, adding or/and modifying the quantity and terminology regarding flint types and their varieties.

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