THE EXPLOITATION OF LOCAL LITHIC RESOURCES DURING THE LATE PREHISTORY OF NORTHWEST IBERIAN PENINSULA

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This paper explores the basic characteristics affecting the mechanical behavior of non-flint rocks, such as quartz and slate, during knapping. The impact of some of these features, such as anisotropy, cleavage, and the morphostructure on the selection and exploitation processes of quartz and slate is addressed through the analysis of the flaked assemblages of five Late Prehistory sites from NW Iberia. We suggest that the presence of characteristics providing a more homogeneous and controllable mechanical behavior would have had a significant role on the selection and exploitation of these raw materials. Also, certain traits a priori *considered as non-suitable might be contemplated as rather advantageous for the knapping.*

KEYWORDS: *NW Iberia, Quartz, Slate, Anisotropy, Cleavage, Morphostructure*

The lithic assemblages recovered in five archaeological sites from the Northwest of the Iberian Peninsula (Figure 1), spanning from the earlier fifth to the beginning of the second Millennium cal. BC (Early Neolithic to the Early Bronze Age), have been studied. These are quite representative of the variability existing in the area at that time, including several domestic sites, a burial mound, and a rock-shelter with rock art adjacent to a large fortified site. They also present a variable preservation, with sites affected by heavy post-depositional processes or by the selective retrieval of lithic material during the archaeological intervention.

The study area is characterized by a lithology that is mainly composed of igneous and metamorphic rocks and also a huge number of quartz veins. Cryptocrystalline materials such as chalcedony, opal, or jasper can only be found in small deposits and they were barely exploited during the Late Prehistory. Thus, lithic industries are mostly made on local non-cryptocrystalline raw materials (Figure 2), while flint is scarce and generally non-local (Rodríguez Rellán et al. 2009).

Given the character of the lithic assemblages analyzed, this paper will be focused on the study of the most representative local raw materials exploited in the area: quartz and slate. First, the characteristics of these raw materials will be described, including the basics of their mechanical behavior. Subsequently, we shall address the potential impact of such traits on the selection and procurement strategies and on the technical aspects of their exploitation too, maybe determining the final characteristics of the assemblages recovered in the archaeological sites analyzed here.

DESCRIPTION OF THE STUDIED SITES

The sites described in this paper are found in different regions of Northwestern Iberia: a coastal territory – the Morrazo Peninsula (Pontevedra) – and two inland areas, the Deza (Pontevedra), and the Aliste (Zamora) counties (Figure 1). Three of the sites (Os Remedios, O Regueiriño, and Lavapés) are located at the Morrazo, while the remaining two in each one of the inland regions (Chousa Nova I-Campo Marzo and Santuario, respectively).

Os Remedios (Moaña, Pontevedra) is a big domestic site, with an extension of more than 4.300 m^2 and a rich structural evidence, including a palisade more than 70 m long, pavements, hundreds of postholes, etc. (Bonilla Rodríguez et al. 2006). The archaeological data and the C^{14} dates suggest that this site was periodically occupied, with varying intensity, from the local Early Neolithic to the Early Bronze Age. The other two sites in the Morrazo Peninsula, also of domestic nature, are smaller and with preservation

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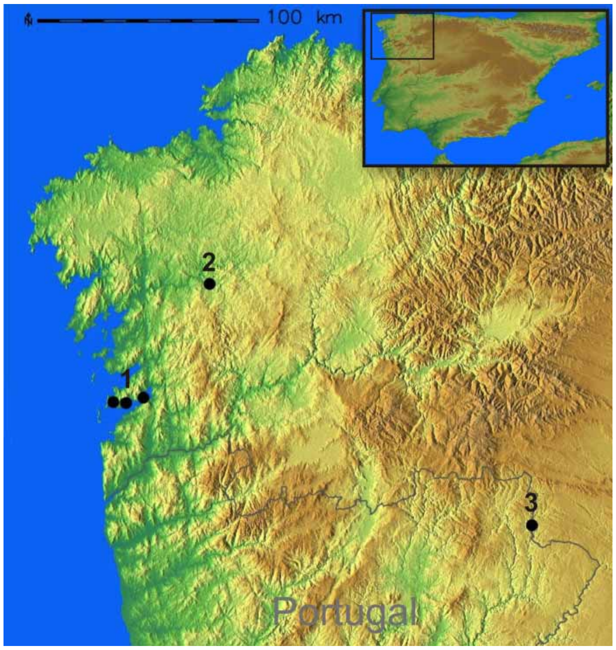

FIGURE 1. Archaeological sites analyzed in this paper: 1. Morrazo Peninsula sites (from left to right: Lavapés, Os Remedios, and O Regueiriño) and inland sites, 2. Chousa Nova I, 3. Santuario.

problems that difficult their study: O Regueiriño (Moaña, Pontevedra) was severely altered by post-depositional processes that included episodes of strong erosion that wiped out most archaeological remains. Despite this, the digs documented a quite large number of artifacts, corresponding to at least two different occupations dated to the Neolithic and Early Bronze Age (Prieto-Martínez 2010). Lavapés (Cangas, Pontevedra) revealed little structural evidences but a big artifact collection, including more than 5000 sherds. The C^{14} dates evidenced that this site was used during the Late Neolithic and Early Bronze Age.

Among the inland sites, Chousa Nova I-Campo Marzo (Silleda, Pontevedra) is a burial mound 21 m long and 1.5 m high, containing the remains of an allegedly individual burial. According to a single C^{14} recovered in the layers beneath the mound, its construction started before the beginnings of the fourth Millennium BC (Domínguez-Bella and Bóveda 2011). A hundred meters away of Chousa Nova I, limited surveys made in the Campo Marzo sector retrieved lithic collections mainly composed by jasper and quartz, derived from episodic occupations probably related with the construction of Chousa Nova I or any of the other mounds nearby.

The Santuario (Trabazos de Aliste, Zamora) is a small rock-shelter displaying schematic art and located on the side of a granitic hill called El Pedroso, in the top of which a large fortified

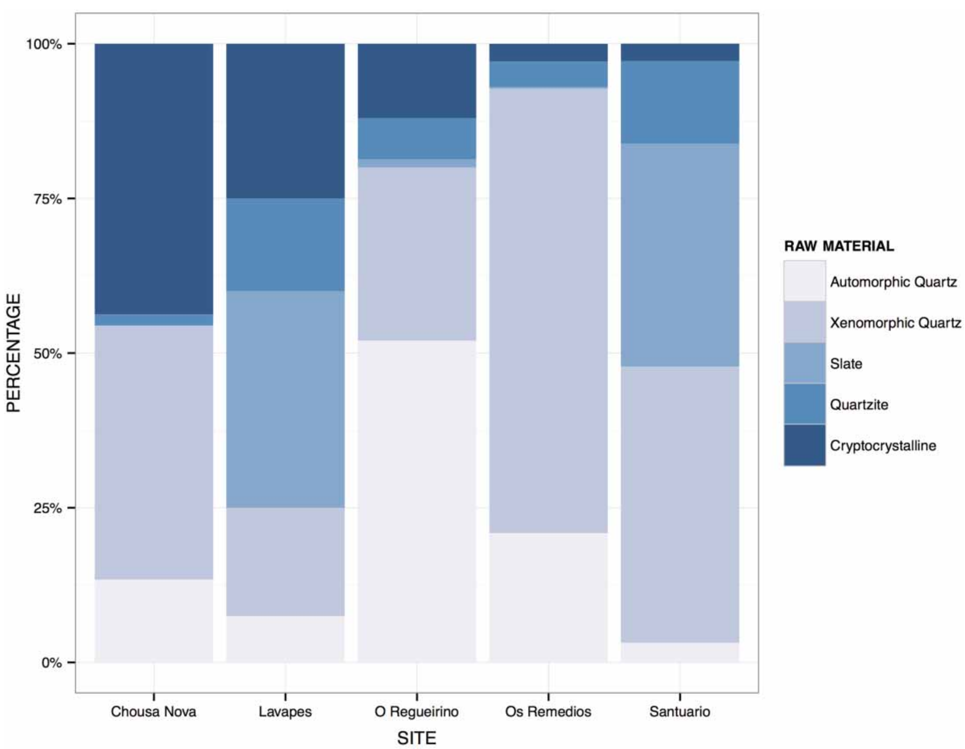

FIGURE 2. Raw material composition of the analyzed assemblages.

site – La Ciudadela (the Citadel) – was built (Alves et al. 2013). The findings inside the rock-shelter, together with the presence of rock art, suggest the possibility of this area having a funerary-ritual nature. On the other hand, the construction of a small dwelling at the cavity's entrance where cooking and knapping activities were documented signals the likelihood of the area having also a domestic nature, at least during some of its occupation episodes. The C^{14} dates pointed out that both the Citadel and the rock-shelter were occupied during most part of the third Millennium BC, corresponding with the regional Late Neolithic and Chalcolithic.

The lithic assemblages recovered in these sites show a variable size, although with a strong predominance of small sets (a common characteristic of most Late Prehistory sites in Northwestern Iberia). Their richness is related – to some extent – with the structural importance of each site (thus, Os Remedios and the Santuario have the largest collections, with 703 and 502 flaked artifacts, respectively) but also with their level of preservation. The latter affects especially to O Regueiriño, whose tiny assemblage (75 artifacts) is probably due to the losses inflicted by the aforementioned post-depositional processes. In turn, the small size of the Lavapés flaked set (40) is related to selective retrieval during the archaeological dig, conducted at the beginning of the 80s. This has mainly affected to quartz industries, unrecognized by the archaeologists due to their lack of familiarity with this raw material. Both natural and artificial processes have obviously limited our understanding of the lithic assemblages of these sites.

Despite their differences, all these assemblages share several characteristics, such as the absence of complex knapping strategies, the scarcity of retouched artifacts, and above all the absolute preeminence of local raw materials, specially quartz, which represents the 71.4% of the flaked sets (Figure 2). Slate and other metamorphic rocks are also important, specially in the Santuario, where this raw material was the second more intensively exploited, as also happened in other areas of El Pedroso complex, such as the Citadel, where a massive manufacture of thousands of slate and lydite arrowheads has been documented (Alves et al. 2013). Other than these, quartzite and cryptocrystalline rocks occur in low number, with the exception of Chousa Nova I-Campo Marzo, where a local variety of jasper was knapped.

Brief Characterization of Quartz and Slate

Due to its ubiquity, quartz was intensively exploited all around the World during the prehistory. Nevertheless, apart from remarkable contributions (Barber 1981; Broadbent and Knutsson 1973; Flenniken 1981), quartz was somewhat ignored by the archaeologists until recently (Ballin 2008; Driscoll 2011; Mourre 1996; Tallavaara et al. 2010). Something similar can be said about metamorphic raw materials such as slate, phyllite or schist, which – except for the "siliceous" varieties (Callahan 1979; Whittaker 2004) – have not traditionally been considered suitable for the knapping (Andrefsky 1998; Odell 2004); although slate or schist have been used as raw material in many parts of the world (Baales 2001; Oliveira Jorge 1986).

This comparatively scarcity of specific studies has resulted in a lack of knowledge about the general characteristics of these raw materials and how they might have affected the knapping. In this paper, we have tried to partially overcome some of these limitations through the definition of their basic mechanical characteristics. For this we have used an Equotip Proceq hardness tester, a device consisting of a piston that rebounds against a solid surface; the quotient of impact and rebound velocities of this piston will indicate the hardness of a material based on the Leeb's hardness test (in a scale of 0–1000). Its general features are close to those of the Schmidt hammer, which has already been used for assessing the mechanical characteristics of lithic raw materials (Braun et al. 2009; Eren et al. 2014).

Although less accurate than other laboratory methods (e.g., Yonekura, this volume), Equotip is an economic, simple, and above all unaggressive method to determine the hardness, tensile stress, or weathering degree of a specific solid (Aoki and Matsukura 2008). Its low invasiveness makes it a good alternative for conducting experiments in archaeological monuments (Mol and Viles 2012), and its worth for assessing some mechanical characteristics of lithics was already noted in former works (Rodríguez-Rellán et al. 2011).

In this paper, we have adopted a classification of archaeological quartz based on its origin, habit, and rock texture; this distinguishes between two main groups: xenomorphic and automorphic quartz (Mourre 1996). The first has a variable appearance and is also the most common: a solid polycrystalline aggregate with an anhedral texture formed by a close-packed mass of crystals that are not usually bounded by their own crystal faces but have their outlines impressed on them by the adjacent crystals (Allaby 2008). Xenomorphic quartz has been usually called "milky," "saccharoidal," or "vein quartz." The automorphic quartz, for its part, is an euhedral mineral with the shape of a well-developed, big hexagonal single crystal terminated alternately by major and minor rhombohedral faces (Sunagawa 2005); it is usually named "rock crystal," "crystal quartz," or "hyaline quartz" by the archaeologists.

Despite the evident problems of the classification of raw materials based on macroscopic analyses, this kind of categorizations can sometimes be very useful at an operational level if based on objectified methodologies supported by more rigorous analytical methods. This is the case of the macroscopic system for the classification of quartz proposed by C. Llana (Martínez Cortizas and Llana Rodríguez 1996), based on the identification of "morphostructural varieties." Such method relies on the identification of two variables:

1. Grain (G): this term refers to the existence of small, well-defined crystalline units that conform a solid polycrystalline aggregate. Regarding its approximate size (less or more than 1 mm), grain can be fine or coarse.
2. Planes (P): this term identifies the existence of crystallization planes, fissures, flaws, or fractures that reach a significant extension (their importance depending on their frequency or the area they occupy).

Thus, the morphostructural classification of quartz is based on the presence (Y) or absence (N) of both characteristics, resulting in four different morphostructural groups (Figure 3):

- NN (no grain/no planes)
- NY (no grain/presence of planes)
- YN (presence of grain/no planes)
- YY (presence of grain/presence of planes)

For their part, the metamorphic materials such as slate or phyllite are crystalline and microgranular rocks which main feature is their foliation or fissility, also known as "slaty cleavage" (the separation of plates or sheets arranged in parallel). They show a high variability in terms of color, hardness, and compactness. Sometimes, such variability has caused some problems to archaeologists, who have used interchangeably terms such as shale, slate, or schist and also adjectives such as "siliceous" or "silicified slate" for mistakenly identifying rocks as metamorphosed lutite or lydite. In our experience, the only way to conduct a reliable characterization of these raw materials is through geochemical and petrographic analysis such as XRD, XRF, and thin section. This will allow archeologists not only to clearly identify the specific raw material with which they are dealing and its possible origin, but it also helps to understand some of its mechanical characteristics (Rodríguez-Rellán et al. 2011).

MECHANICAL PROPERTIES OF QUARTZ AND SLATE

The three types of non-cryptocrystalline local raw materials (automorphic and xenomorphic quartz, metamorphic rocks) often show lower hardness than the chalcedony, jasper or flint, but – at the same time – a much higher variability of their values (Figure 4). This can be related with their internal homogeneity, such as the existence of "discontinuities" within the raw material (caused by flaws, fractures, inter-granular spaces, or inclusions) or by specific physical properties such as anisotropy or cleavage. Such discontinuities and irregularities would have some impact during the knapping, increasing the probability of accidents, and even hindering its development as a controlled process.

A good example is the automorphic quartz. Due to its conchoidal fracture and homogeneity, this raw material was initially considered to have a good quality for knapping (Callahan 1979). Nevertheless, this view changed when researchers noted that its knapping was quite different from that on cryptocrystalline rocks (Reher and Frison 1991), mainly due to its anisotropic nature (Novikov and Radililovsky 1990), which led to a remarkable variability in the ease of fracture depending on the direction it was worked.

The Equotip analyses made on several samples of automorphic quartz suggest that, indeed, the anisotropy of quartz crystals would have some effect on the progression of the mechanical forces: those readings made parallel to the longitudinal axis of the crystal show a higher hardness than those made on perpendicular and, above all, oblique directions to the aforementioned axis (Figure 5, Sample 2). This matches the results of other specialists (Bloss 1957; Rességuier et al.

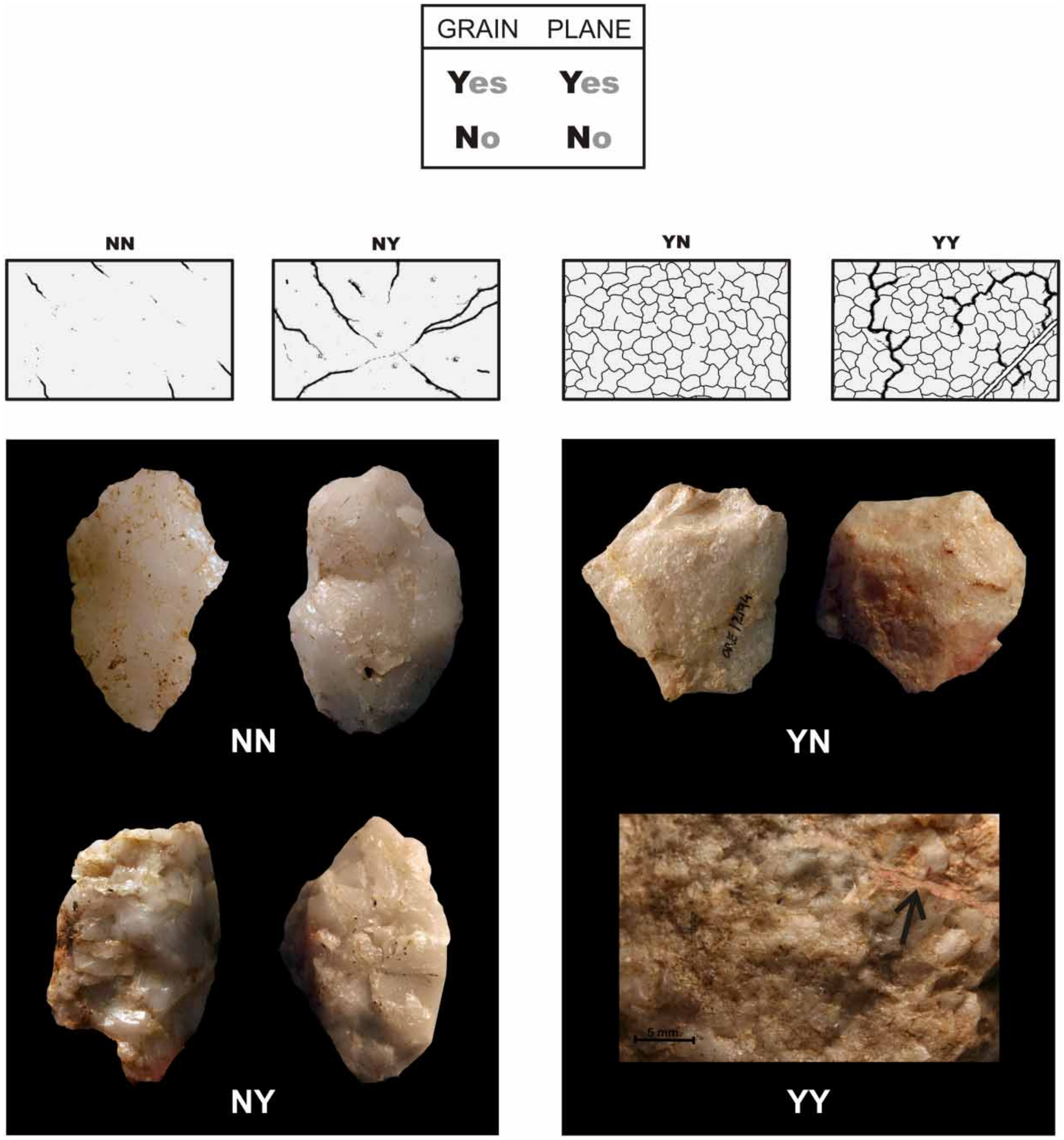

FIGURE 3. Quartz morphostructural groups.

2005), who also suggested that the structure of quartz crystals seems to be weaker precisely along those oblique planes. However, in some samples, the longitudinal lectures were those with the lower and most variable values (Figure 5, Sample 1). This circumstance is related with the presence of flaws and inclusions in the basal area of the crystals, implying a lower hardness of the material there (Westbrook 1958). Such flaws – perceptible in the greater variability of the readings in specific points as compared with those crystals with less internal flaws (Figure 6) – seem to affect the homogeneity and continuity in a more important way than anisotropy does. Therefore, internal planes might be a greater problem during knapping, as other authors have already noted (Cotterell and Kamminga 1987; Novikov and Radililovsky 1990).

Anisotropy affects all the tectosilicates of the quartz group; nevertheless, polycrystalline aggregates of xenomorphic quartz can act – due to the small size and random orientation of their anisotropic crystals – almost isotropically in a macroscopic scale. This dynamic has been called "isotropy by compensation" (Mourre 1996) and could imply a better quality for the knapping of the polycrystalline aggregates of xenomorphic quartz (YN and YY morphostructure). Still, these raw materials are affected by what can be a bigger problem: its grainy

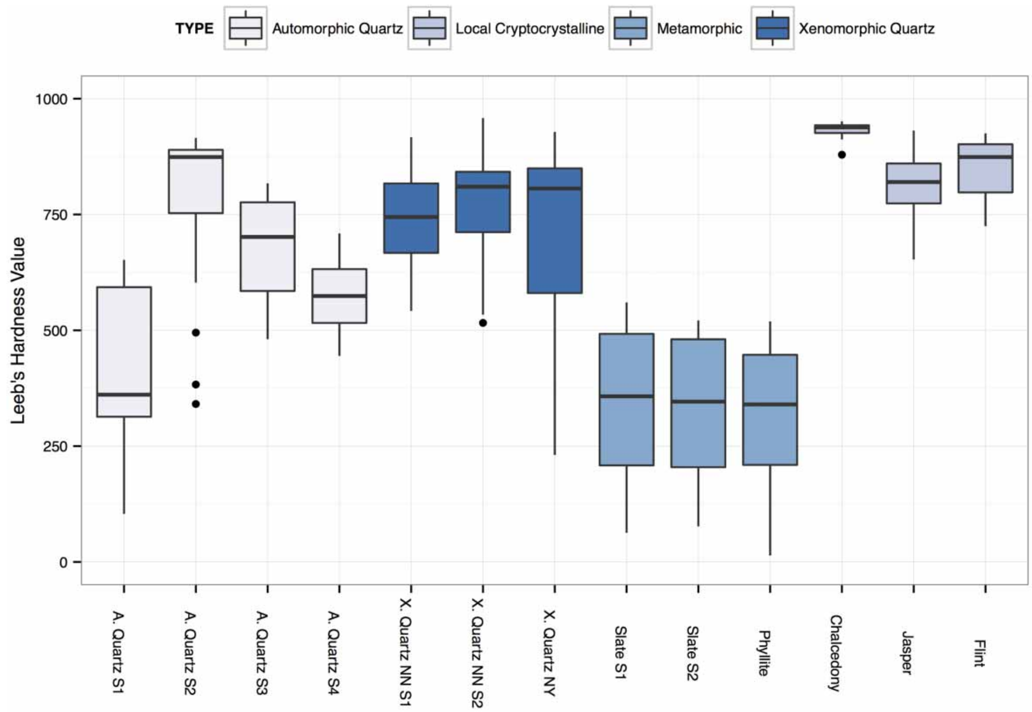

FIGURE 4. Leeb's hardness value from different samples of automorphic and xenomorphic quartz, slate, phyllite and other local cryptocrystalline raw materials, measured using the Equotip hardness tester.

structure. Thus, the fractures on grainy materials tend to occur along the inter-granular spaces, where the material is usually less resistant. This can lead to irregular fractures or even to premature terminations, factors deeply affecting the knapping.

Another element has to be taken into account on the xenomorphic quartz: since most internal fractures are caused by external tectonic forces taking place during the epigenetic stage (Vollbrecht et al. 1999), these tend to affect xenomorphic quartz to a much greater extent, since it is formed in the outer parts of the veins and, therefore, more intensively subjected to the pressure of the surrounding materials. Meanwhile, the automorphic quartz – while formed in small crystallization hollows in the inner parts of the veins – has been generally less affected by such pressure, and fractures or flaws are commonly occurring only in the basal parts, as we have already pointed out. Like automorphic quartz, the presence of such planes and flaws becomes an obstacle for the progression of forces like those acting during the knapping. As can be seen on the Figure 4, the presence of planes in the xenomorphic sample with a NY morphostructure has led to a comparatively higher dispersion of the lectures detected by the Equotip, caused by the weak areas in which these flaws are found. This can also be seen on the Figure 6, where some of the readings show marked decreases in comparison with the xenomorphic samples with a NN morphostructure.

Regarding the metamorphic raw materials, several analyses were made using Equotip on the main varieties of slate and phyllite exploited in the Santuario site. The readings were distributed according to their orientation with respect to the cleavage planes (perpendicular, oblique, and parallel to them) (Figure 5). The results show a significant relationship between the rebound of elastic waves and the inclination with respect to the direction of such planes (Rodríguez-Rellán et al. 2011). Thus, resistance is much higher when impacts are run perpendicularly to the cleavage planes and, therefore, the penetration of a mechanical force applied will be much less if done in this direction. Exactly the opposite happens when impacts occur in a parallel orientation, where the rebound is drastically reduced. This is related with the fact that the elastic waves and other mechanical forces advance much more easily along these cleavage planes composed by softer sub-parallel layers or mica and other materials (Rodríguez Sastre and Calleja 2004). Such characteristic has a major

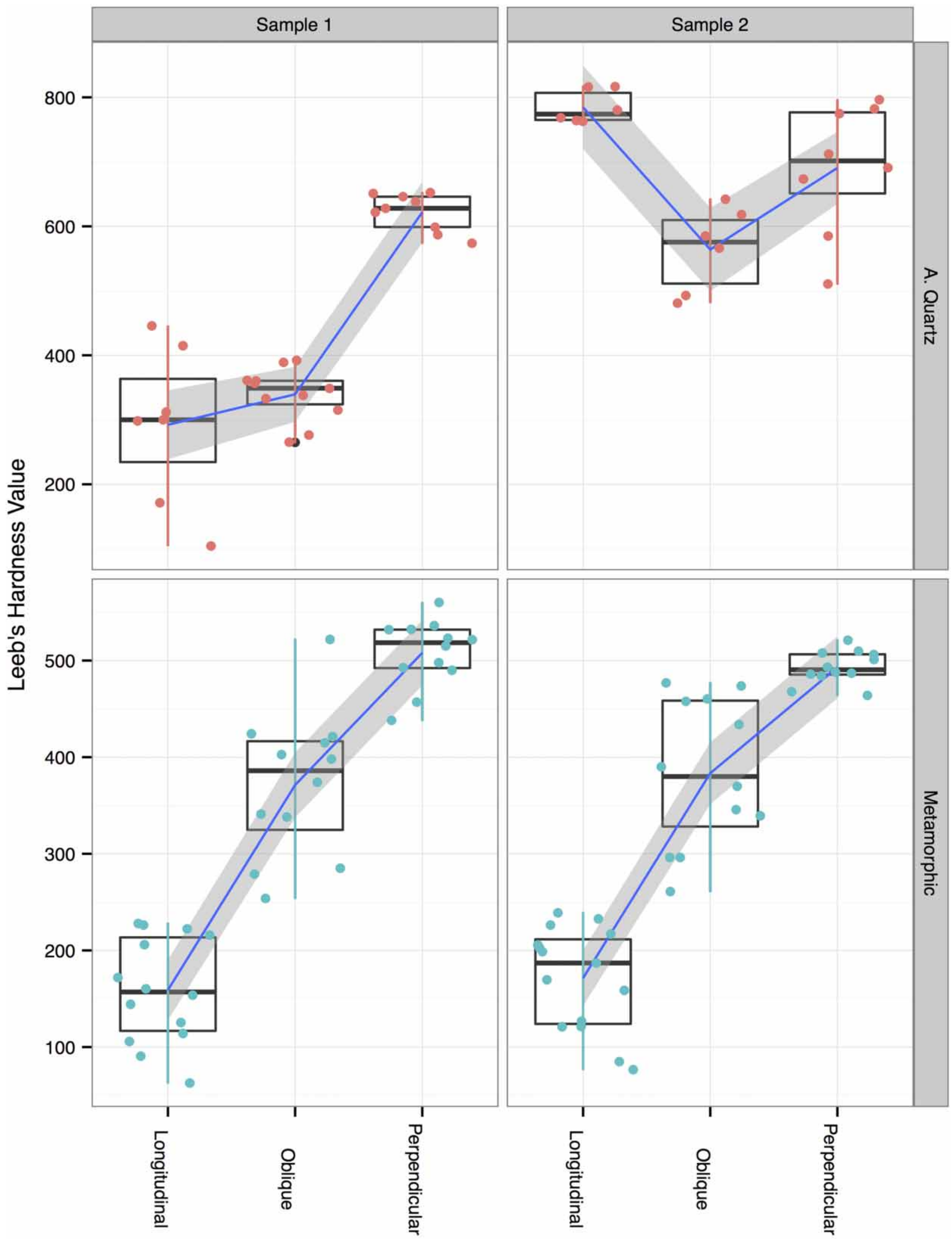

FIGURE 5. Directional anisotropy detected in automorphic quartz and Metamorphic rocks according to the longitudinal axis of the crystal (A. quartz) and the cleavage planes (metamorphic).

impact on the fracture parameters of these rocks (Lérau et al. 1981).

PROCUREMENT OF THE LOCAL LITHIC RESOURCES

The analysis of the lithic assemblages has been complemented with geological surveys. During this process, several samples were collected for their petrographic and geochemical analysis and

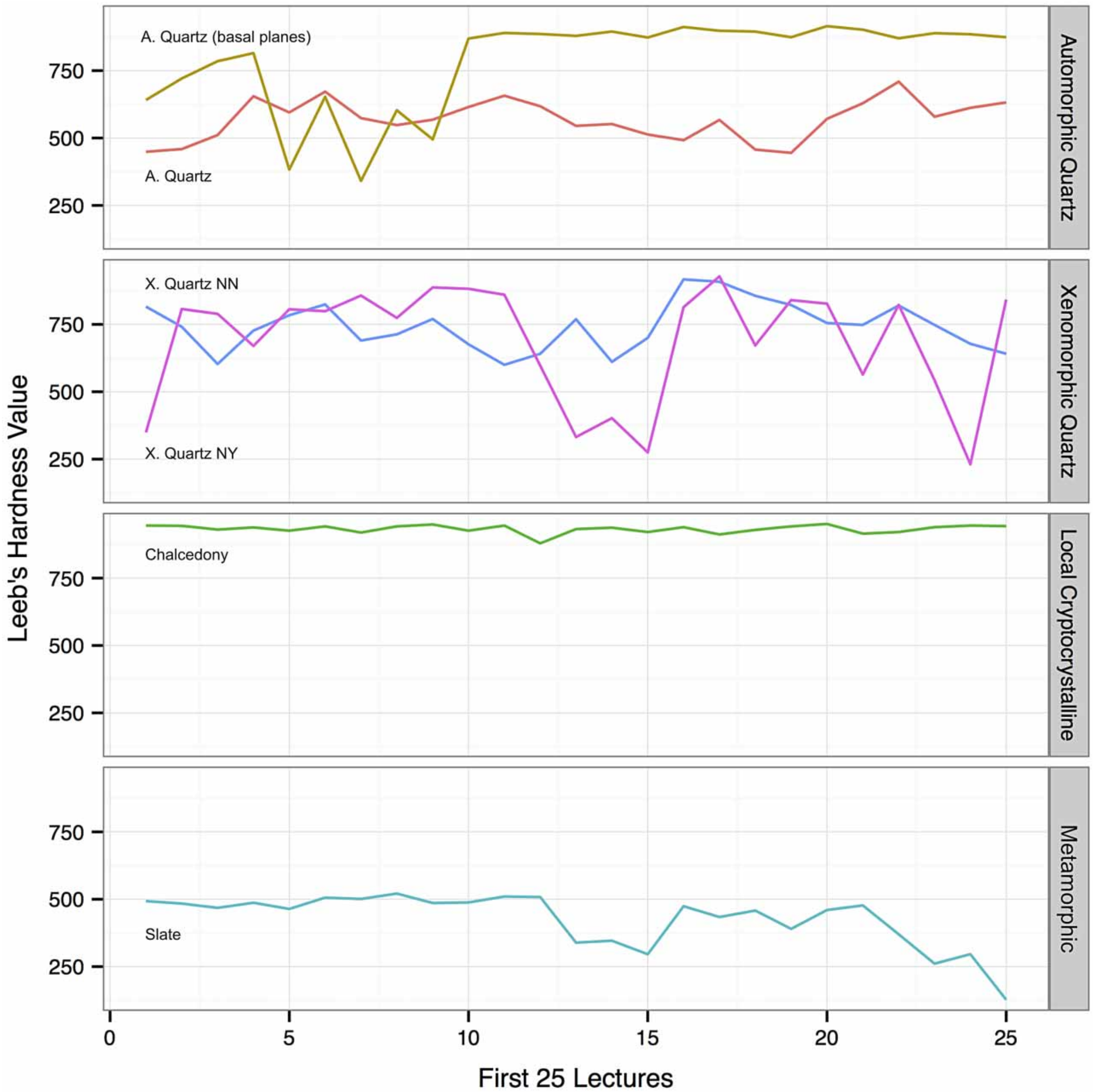

FIGURE 6. Leeb's hardness value shown by the first 25 lectures made on different raw materials using the Equotip hardness tester.

the results compared with those conducted on archeological materials. This has allowed us to identify – with some degree of confidence – the origin of part of the raw material exploited in the sites described here.

The results of these surveys evidenced the existence of an important number of potential procurement areas – both of primary and secondary nature – very close to the sites, especially for quartz, slate, or quartzite (Figure 7). The first raw material is very abundant in the NW of the Iberian Peninsula, not being difficult to find a huge number of quartz veins and dykes scattered all around the landscape. The quality changes both between different veins and within the same formation: in some cases – Lavapés, Os Remedios, or Chousa Nova I – the closest primary resources would have provided top quality varieties, such as translucent, non-grainy xenomorphic quartz, and automorphic crystals. Yet, in other areas it is comparatively difficult to find specific types of quartz, especially automorphic crystals big enough for knapping. This is the case of the Santuario, and it might be the reason for the scarcity of prisms there.

Slate and other metamorphic raw materials such as schist and phyllite can also be found in the proximities of most sites. This abundance is especially evident around the Santuario, where polimetamorphic rocks of Silurian and Devonic age dominate. Among these, there are different varieties of slate, including a very common gray-

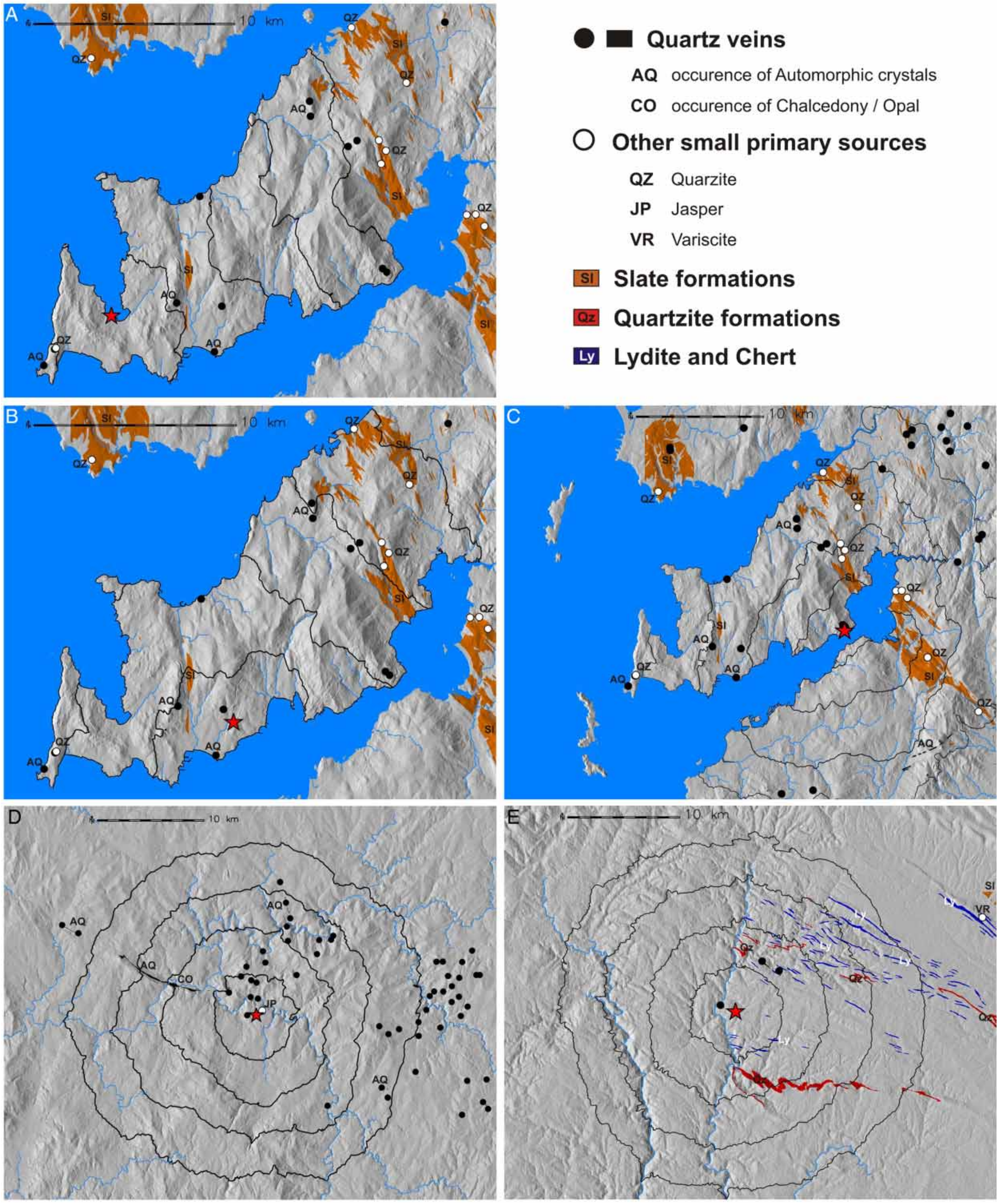

FIGURE 7. Location of the different archaeological sites analyzed in this paper (A) Lavapés, (B) Os Remedios, (C) O Regueiriño, (D) Chousa Nova I, (E) Santuario) and their 4 h isochrones. The location of the main primary resources detected during the geological surveys is also marked.

greenish type with little compactness, whose formations extend for kilometers on both sides of the Spanish-Portuguese border. The analysis of composition made on geological and archaeological samples suggest that the gray slate used in most arrowheads of the Santuario sector was quarried in these formations.

Potential secondary sourcing areas have been also documented. Since none of the archaeological sites in the Morrazo Peninsula is located more than 2 km away from the present coastline, it is likely that the shore would have played a major role in the acquisition of stone material, as shown in Os Remedios (Bonilla Rodríguez et al. 2006). In the inland sites, this role was probably played by the nearest watercourses, such as the Ulla, Deza, and Manzanas rivers (Figure 7). The exploration of riverbanks within the 2 h isochrones from the Chousa Nova and Santuario sites recorded the existence of a high variety of raw materials, including quartz, slate, quartzite, lydite, and even low-quality cherts.

The composition analyses and the macroscopic characteristics of the raw materials conforming the flaked assemblages allowed us to identify the nature of the sourcing areas. Quartz shows different origins depending on whether its nature is automorphic or xenomorphic. Not surprisingly, the first variety was directly collected from the quartz veins (Figure 8), in part due to the difficulty of finding this kind of blanks on the secondary sources. Meanwhile, xenomorphic quartz shows a much more variable situation: in some of the sites, such as Os Remedios and Santuario, a relative equilibrium between primary and secondary blanks can be seen. Secondary origin varieties are, in turn, predominant in O Regueiriño, while primary dominates in Lavapés and Chousa Nova. The number of primary blanks at the latter could be related with the huge quartz vein (Pico Sacro formation), just 1.5 km north, where a wide variety and quality of quartz can be found.

Slate and other metamorphic raw materials also show different trends depending on the site: in Lavapés and Os Remedios their origin is secondary, while in O Regueiriño is mainly primary. The latter is probably due to the proximity of the slate masses amidst the Malpica-Tuy Band Formation (Figure 7). Nevertheless, in all these sites, the metamorphic set is too small for their analysis achieving representative results. This is not the case of the Santuario, where slate and other metamorphic rocks are numerous and show an almost exclusive primary origin, specially among the gray slate, the variety most intensively exploited here (167; 92.2%); meanwhile, the very scarce secondary blanks are mainly related with the black slate or lutite. This is consistent with the geological characteristics of the surrounding landscape, where the gray-greenish variety is very abundant while the lutite is scarce, as evidenced by the failure to find its original formations, being documented only occasionally among the secondary blanks in the riverbanks of the Manzanas river. On the other hand, a procurement strategy based on the exploitation of primary resources seems to be more appropriate for the type of specialized knapping recorded at El Pedroso, since the high levels of production could only be adequately sustained by regular and – to some extent – organized extractive activities.

The characteristics of the raw materials suggest the existence of a relatively diversified procurement strategy, quite equilibrated between the exploitation of primary and secondary sources, mostly within the 4 h isochrones (Figure 7) and, in some cases, visible from the sites. Therefore, it could be assumed that part of these sources were located within the area that was the scene of the daily activities and that would be economically and ideologically appropriated by the group. At the same time, the exploitation of strictly local resources would probably mean that the quality of raw materials would have been deeply conditioned by local geology, sometimes rather poor.

Eventually, the need for quality raw materials, such as automorphic crystals, would have implied distant expeditions, though seldom longer than a day. These exceptional raw materials could have also been acquired in the framework of seasonal mobility among the different patches of the settlement network, which allegedly would have include central sites, such as Os Remedios, and smaller campsites, such as O Regueiriño and, maybe, Lavapés (Fábregas Valcarce 2010). Finally, the exchange with other local and regional groups could also give access to flint and other non-local items (Rodríguez Rellán et al. 2009).

PARAMETERS OF SELECTION OF LOCAL RAW MATERIALS

A thorough analysis of the characteristics of the quartz and slate collections evidenced the existence of differences regarding their procurement strategies. The morphostructural classification has allowed us to identify specific parameters that might have operated during the selection of quartz. Thus, the morphostructural analyses show a predominance of non-grainy (NN and NY) over grainy (YN and YY) varieties (Figure 9). This might be partially due to the characteristics of the local sources, as happens with the scarcity or even absence of the YN morphostructure in most sites, reflecting its rarity among both the primary and secondary sources explored during the survey. At the same time, these traits suggest that the absence of "grain" was a major element in the selection of quartz, over the presence of internal planes (maybe due to the usual difficulty of detecting these imperfections).

Furthermore, the analysis of the morphostructural groups of xenomorphic quartz against the nature of the sources suggest that the grainy varieties (YY and YN) were preferentially collected

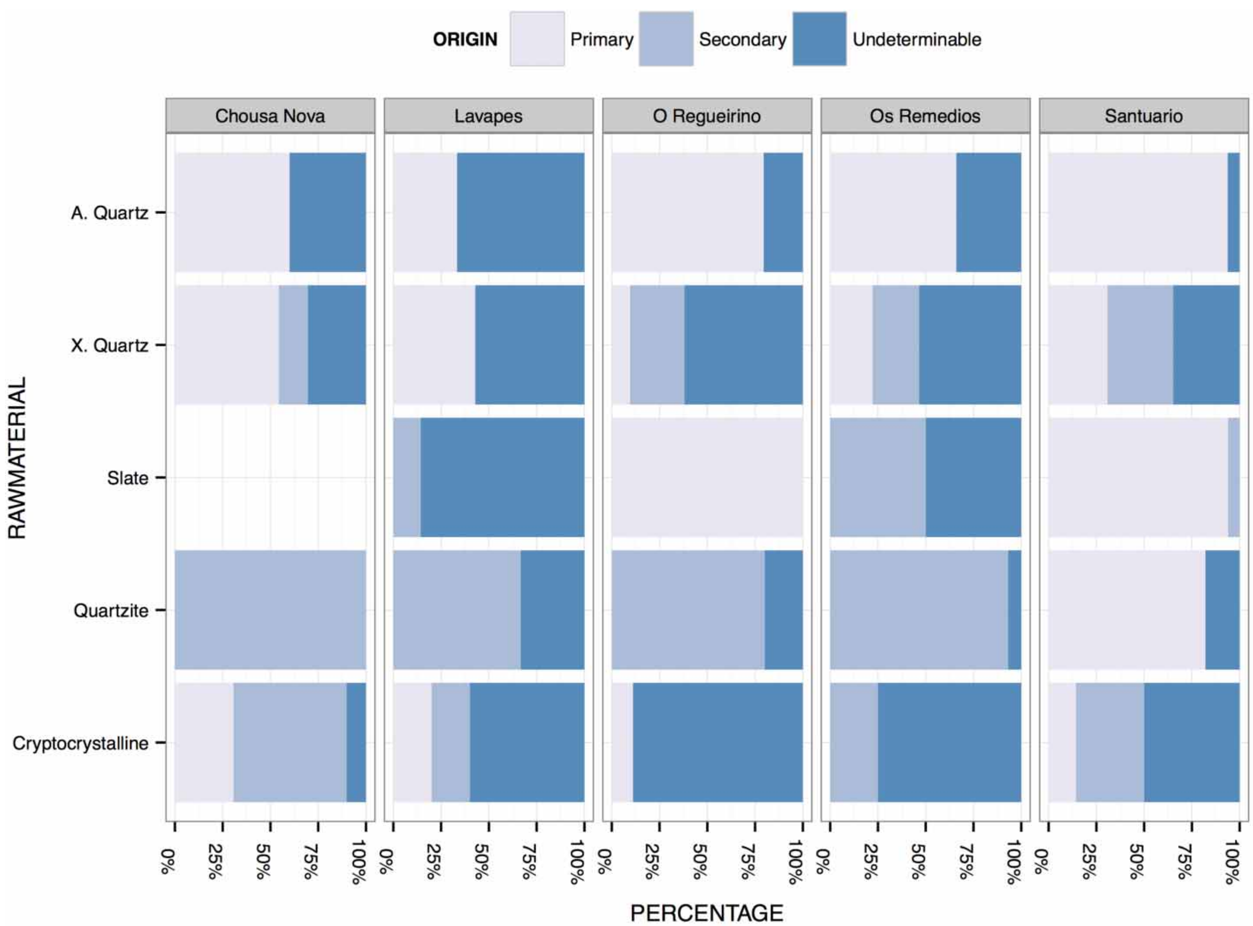

FIGURE 8. Origin of the raw material exploited in the different archaeological sites.

in secondary sourcing areas, while the non-grainy morphostructure (NN and NY) is related to a greater extent with primary sources (Figure 10). This can be seen in Os Remedios and Santuario, but especially in Chousa Nova I-Campo Marzo (90.9% of the material whose origin is

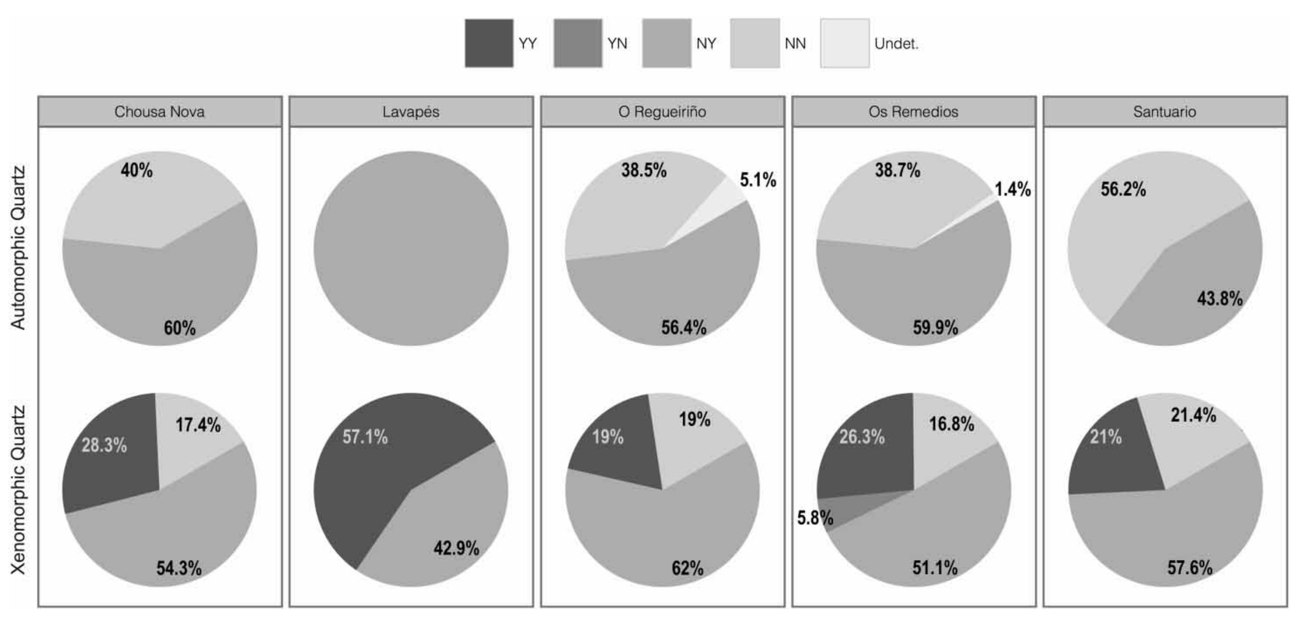

FIGURE 9. Morphostructure of the xenomorphic quartz in the different assemblages analyzed.

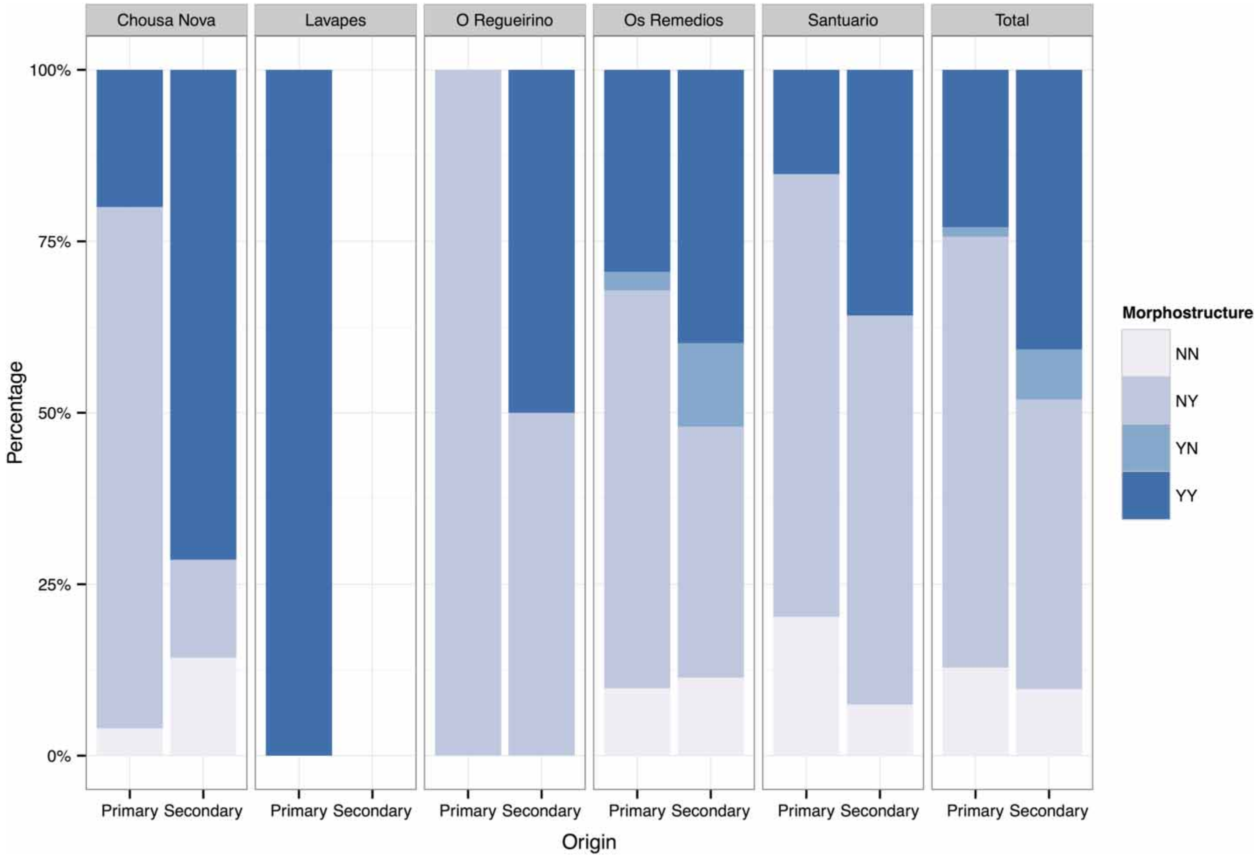

FIGURE 10. Nature of the source according to the morphostructure of xenomorphic quartz.

determinable), pointing to a common trend in all the sites: those varieties of quartz with a higher flaking quality (NN and NY, but also fine-grained YY and YN) tend to have a primary origin, circumstance that might suggest a higher degree of raw material selection than that carried out during the exploitation of the secondary sources. Thus, the greater variability and modest quality of the raw material collected from the latter could be consistent with a more opportunistic procurement strategy.

Automorphic quartz is obviously non-grainy but there is a different presence of internal flaws depending on the site: from the preeminence of varieties with almost no internal planes (NN) in the Santuario, to the dominance of crystals with these imperfections (NY) in the rest of the sites. This circumstance might be related with a different degree of raw material selection, but it is more likely dependent on the character of the local sources: that would explain the higher presence of varieties with internal planes, even when the Equotip analyses show that these imperfections can impair flaking.

Regarding the slate and other metamorphic raw materials, the selection strategy seems different in the Santuario than in any of the other studied sites. While in Lavapés and O Regueiriño this seems to be focused on varieties with higher compactness/hardness and sub-conchoidal or even conchoidal fracture, in the Santuario the selection followed the opposite direction: the most intensively exploited variety of slate was a gray-greenish rock with a relatively modest hardness and low compactness, causing a splintery and highly uncontrollable fracture. One could argue that this preference followed from its huge presence in the local landscape, but – in our view – the option for this specific type of slate despite its mechanical shortcomings was also related with the kind of artifacts manufactured: arrowheads.

SPECIFICITIES OF THE EXPLOITATION PROCESSES

Once evidenced the main factors affecting the mechanical behavior of quartz and slate that might have been taken into account during the selection of these raw materials (a grainy structure, the presence of internal planes, or the degree of compactness), it was necessary to determine if such traits also had an impact during their exploitation, either conditioning the character and complexity of the technical processes, or affecting the nature of the products obtained.

The quartz assemblages analyzed are composed by little more than 1000 artifacts, ranging from 652 in Os Remedios to only 10 in Lavapés, while Santuario (240), Chousa Nova I-Campo Marzo (61), and O Regueiriño (60) have a rather modest size. As already noted (Figure 2), except in the case of O Regueiriño, the quartz assemblages are dominated by the xenomorphic varieties, consistent with their higher presence among the local sources.

The assemblages of both automorphic and xenomorphic quartz are mainly composed of non-retouched flakes (Figure 11), varying from only a 20% in Lavapés (probably due to the selection) to the 63.80% in Os Remedios. The characteristics of these flakes do not point out to the involvement of very complex technical processes: the predominance of thick platforms with barely transformed surfaces (Figure 12) suggests the presence of direct free-hand percussion, while the bipolar-on-anvil would be probably responsible for many linear (LIN) and punctiform (PUN) butts and crushed (CR) surfaces. Nonetheless, there are differences among automorphic and xenomorphic quartz flakes regarding the morphology of their platforms: the larger percentage of bifaceted (BF) and multifaceted (MF) surfaces on automorphic quartz could be interpreted as an evidence of a higher preparation of striking platforms, circumstance that – however – is not observable in the cores of this raw material recovered in the sites. The results of the experimental knapping (Rodríguez Rellán 2010) suggest that the greater transformation of the striking platforms of automorphic quartz flakes might be related to the need for a major preparation of the platform due to the slippery nature of this raw material (similar to obsidian's) and also to its brittleness, demanding a frequently rejuvenation of this plane, specially when using hard hammer percussion.

In the specific case of flakes made on xenomorphic quartz, there seems to exist some relationship between their morphometric characteristics and the morphostructure of the raw material they were made on. The effects of morphostructural groups on the mechanics of flaking have been initially explored for quartz paleolithic industries (De Lombera Hermida 2009). We have hinted, too, at the existence of other previously unidentified effects that specifically affect flakes. The analysis of the platform thickness and, above all, general thickness of these products shows a tendency to flakes made on grainy quartz (YY and YN) having a greater thickness than those on non-grainy materials (NN and NY) (Figure 13). Though apparently feeble, such tendency is statistically significant (KW *P*-value <2.2e-16). What remains difficult to establish is whether this is a direct effect of the mechanical characteristics of the grainy structure or it is caused by the changes made by knappers in response to the characteristics of this raw material. During the experimental knapping of quartz with YY and YN morphostructures, we repeatedly noted the need for applying the force in points further away from the edge of the striking platform, in order to avoid its collapse (caused by the disintegration of the grains by the action of the impacts), therefore rendering thicker flakes with thicker platforms and also more marked bulbs of force. Such circumstance does not happen on non-grainy quartz (NN and NY) due to its higher resistance, allowing us to apply the force in points closer to the edge of the platform and – therefore – obtaining thinner products.

As to the cores, there are unifacial (UF) and bifacial (BF) exploitations in which a relatively important part of these might remain unused. Furthermore, the flaking surfaces show a markedly unipolar character, a lower recurrence and a reduced centripetal character (Figure 14), prevailing the non-centripetal (NC) or barely centripetal (C) strategies over those more markedly centripetal (2C–4C). In short, the recovered cores suggest the existence of not very complex strategies, characterized by non-intensive and barely planned reduction processes. No clear differences are seen between automorphic and xenomorphic assemblages in this respect, but the analysis of the level of exploitation of xenomorphic cores regarding their morphostructural variety points (Figure 15) that the NN and NY varieties were more heavily exploited than the grainy ones (YY and YN), perhaps out of their better quality.

Special attention should be paid to the bipolar-on-anvil technique, since its presence is relatively important in the Santuario, Os Remedios, or Chousa Nova (Figure 16). The use of this technique on quartz has been frequently associated with a kind of "last resource" solution, bent on the exploitation of raw material that – due to its lower quality – would be barely knappable

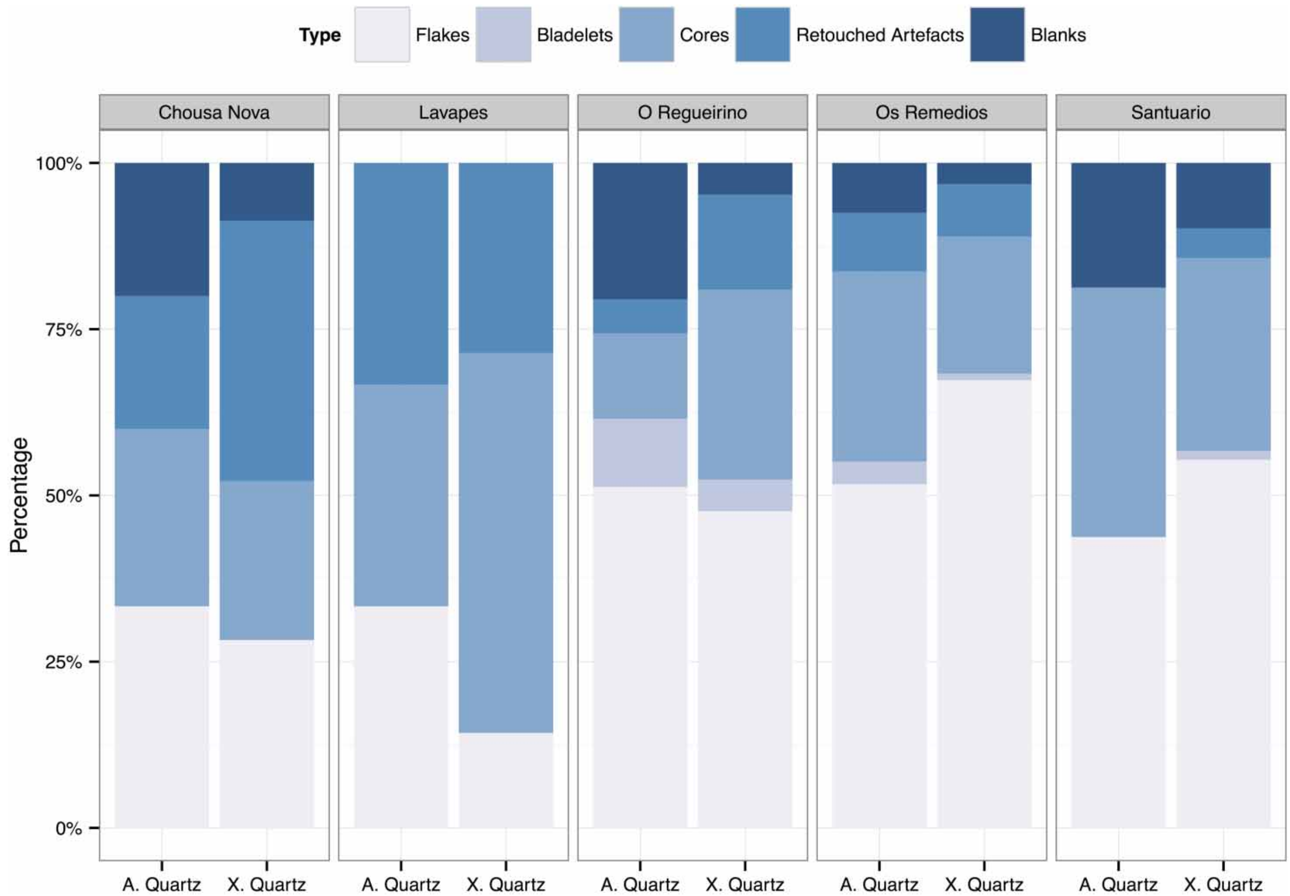

FIGURE 11. Composition of the quartz assemblages.

otherwise. Although such point of view is sometimes bordering material determinism, it is also true that bipolar percussion was undoubtedly used for trying to overcome much of the quantitative and qualitative conditionings imposed by quartz.

This seems to be especially true in the case of automorphic quartz. Both the Equotip analysis and former works evidence the difficult progression of forces along the longitudinal axis of the prismatic crystals. The analysis of archaeological and experimental sets has pointed out the difficulty of the longitudinal exploitation of automorphic quartz except when knapping small crystals or using bipolar-on-anvil percussion (Prous et al. 2012; Villar Quinteiro 1996). The experimental knapping conducted (Rodríguez Rellán 2010) using a wide variety of techniques, showed how – indeed – the longitudinal knapping of crystals bigger than 3 cm only achieves a significant success rate when applying bipolar percussion or pressure flaking (Figure 17). Meanwhile, the direct and indirect percussion only allowed a successful exploitation when knapping the prism along its oblique planes.

Since pressure flaking has not been clearly identified among the studied assemblages, it seems that the only way for the Neolithic and Bronze Age knappers in the study area to conduct a longitudinal exploitation of automorphic crystals would be the bipolar-on-anvil percussion. In fact, this strategy has been reported in most sites (Figure 17); meanwhile, those non-bipolar cores on automorphic quartz show only exploitations along the oblique, weaker planes. This suggests that the anisotropy, although less conditioning than internal flaws for knapping, had – in practice – affected the way in which automorphic quartz was exploited in the sites analyzed here.

Meanwhile, the use of the bipolar-on-anvil percussion in the different morphostructural groups of xenomorphic quartz suggests a more complex situation: the association analysis of this technique against the morphostructure (Figure 18) shows a stronger relationship between bipolar-on-anvil percussion and those varieties with both a lower (YY) and a higher quality (NN). Such

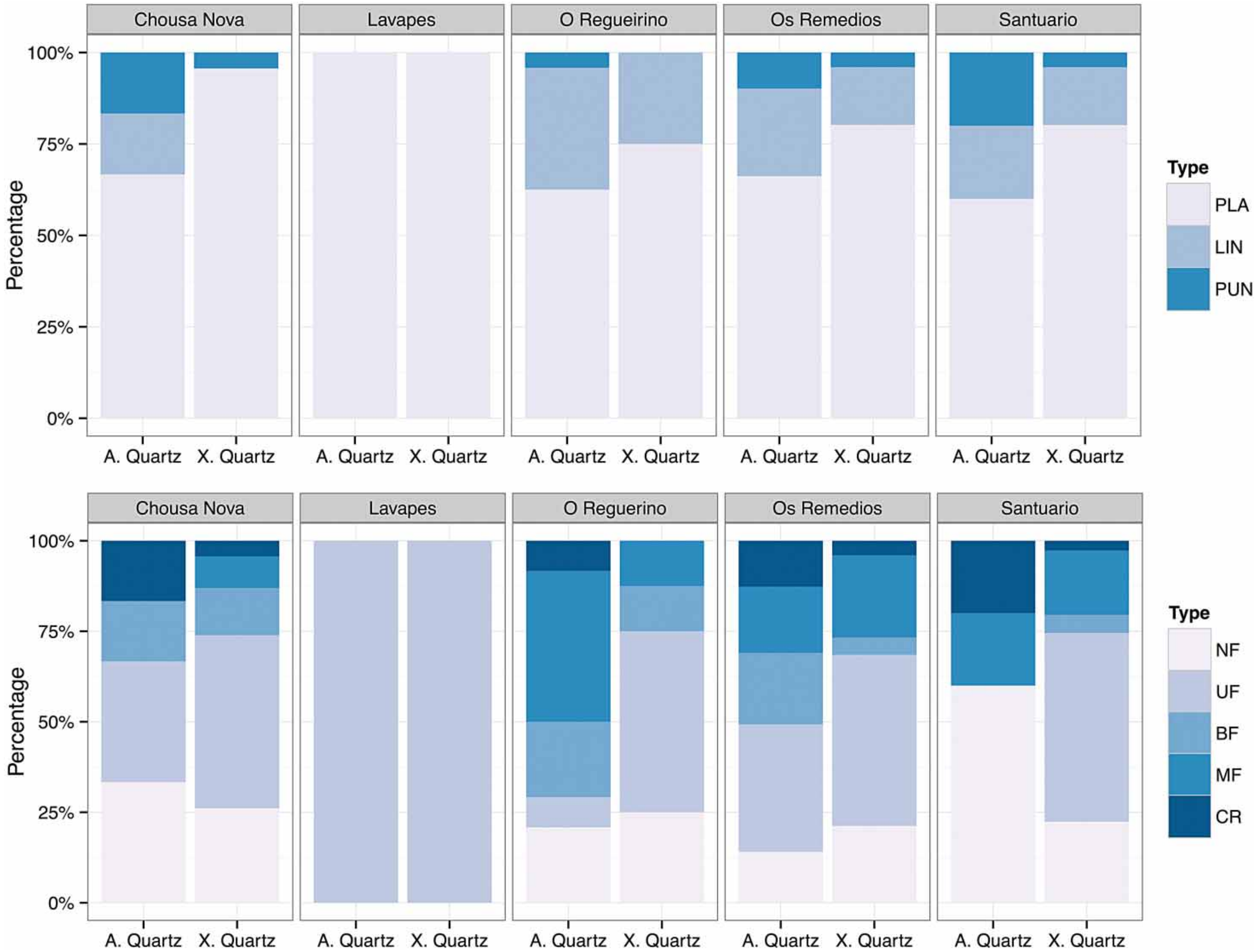

FIGURE 12. Type and transformation of quartz flake butts.

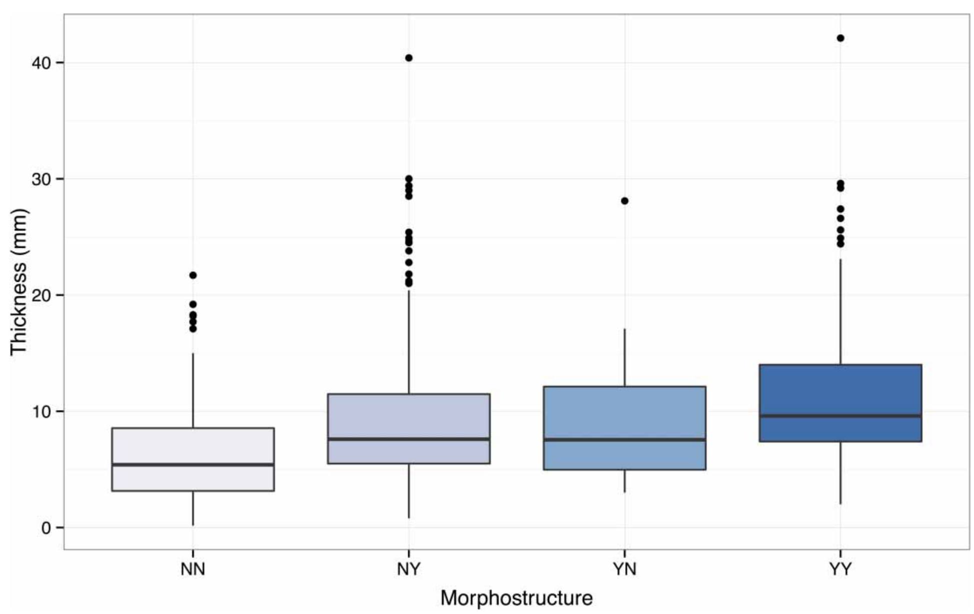

FIGURE 13. Thickness of xenomorphic quartz flakes according to their morphostructure.

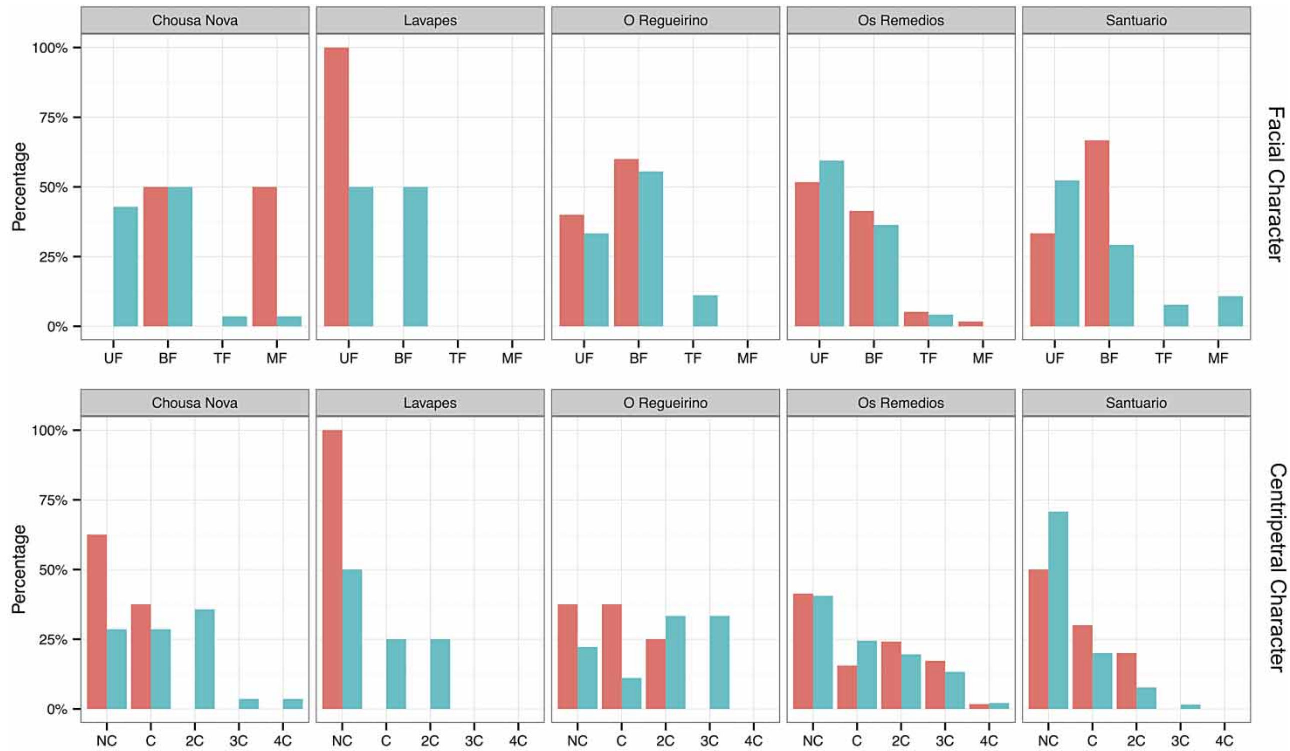

FIGURE 14. Facial character and centripetal character of quartz cores.

circumstance hints at the bipolar technology being applied on automorphic quartz for different reasons: achieving a more intensive and efficient volumetric exploitation of the high quality cores and, beyond that, in order to exploit other cores whose discrete quality made them difficult to flake by free-hand techniques. Therefore, we can assume that the bipolar-on-anvil technology was not just a "last resort" for the exploitation of raw materials with limited flaking qualities, but a technological solution perfectly integrated within the interests and objectives of the prehistoric knappers of the study area.

Bladelets are very scarce in the quartz assemblages studied here (Figure 11). Microblade production does not represent more than 3% of the quartz assemblages, reaching its maximum weight in O Regueiriño (8.33%). This very low index is a common feature of our Neolithic and Bronze Age collections, contrasting with the Upper Paleolithic and Epipaleolithic sites, where quartz bladelets are more frequent (Villar Quinteiro 1996). Nevertheless, as in the previous periods, the Late Prehistory knappers seemed to prefer the automorphic quartz and those non-grainy (NN and NY) varieties of xenomorphic quartz for obtaining this type of products (Figures 11 and 18).

Like bladelets, retouched artifacts are scarce in the quartz assemblages, its percentage seldom exceeding 10% of the total. The only exceptions to this situation are Lavapés (30%) and Chousa Nova I-Campo Marzo (34.4%). In the first site, the weight of these artifacts is related with the aforementioned process of selection; meanwhile, the higher presence of retouched tools in Chousa Nova might be explained by the characteristics of this assemblage: since most part of it appeared scattered among the soil forming part of the tumulus, it is probable that these artifacts had been used and discarded during the process of construction of the Chousa Nova I mound. Thus, it is possible that the higher presence of tools such as scrapers and burins would be related with the woodworking tasks, etc., carried out during the building of the monument.

This group is mainly composed by retouched flakes, while those more configured tools allowing a clear typological ascription are dominated by burins and scrapers. The retouch is mainly abrupt (59.3%) or semi-abrupt (29.6%) and almost no plane retouching is present (3.2%). On the other hand, the retouched area has always a limited extension, being marginal or very marginal in 82.4% of the artifacts, while invasive is present in a 16.4% and covering

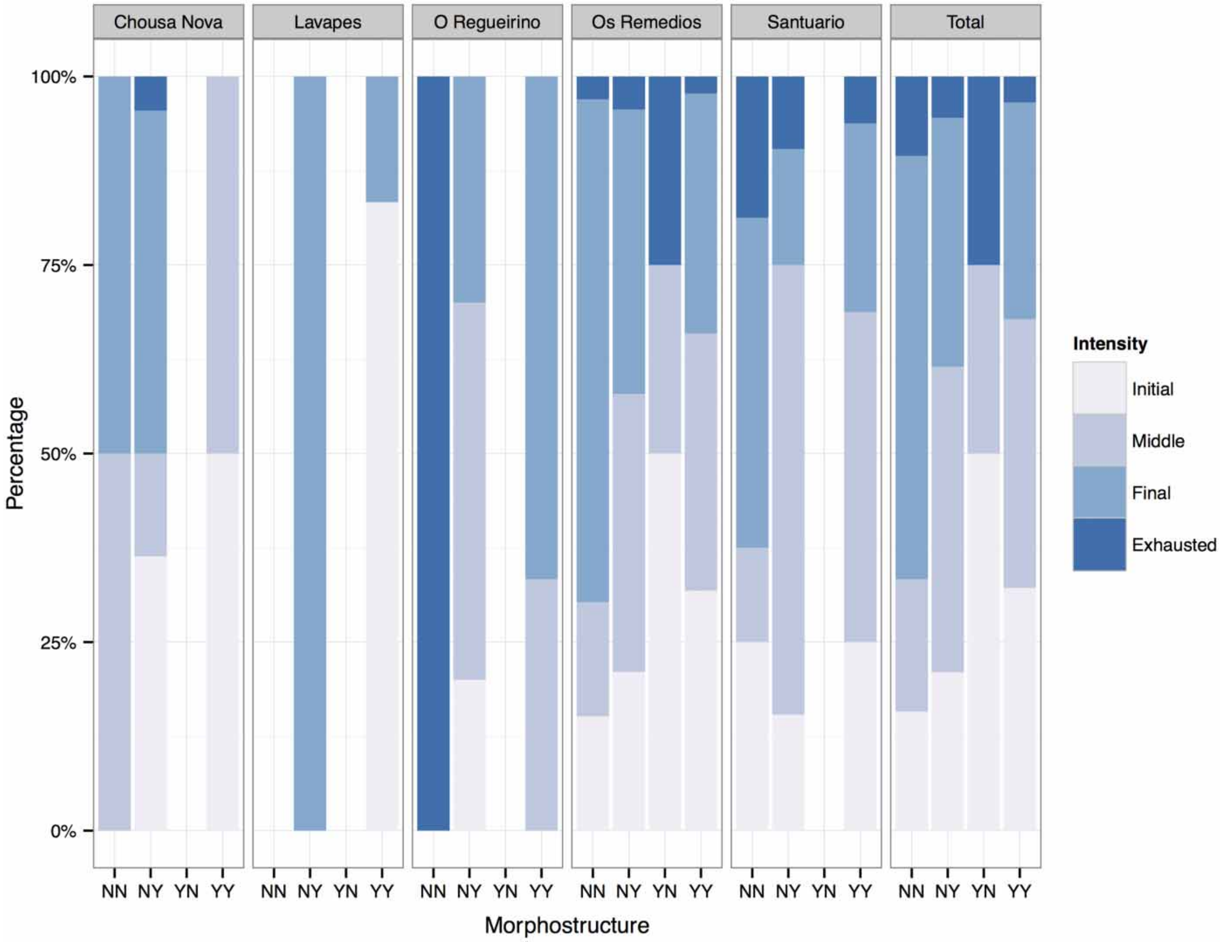

FIGURE 15. Intensity of the exploitation of xenomorphic quartz cores regarding their morphostructure.

retouching has been documented in only one artifact (an arrowhead).

These characteristics are very similar in both automorphic and xenomorphic assemblages and between the different sites, with only a slightly higher presence of invasive retouch on automorphic quartz artifacts. The results of the association analysis between retouched tools and the different morphostructural groups of xenomorphic quartz show, again, a greater relationship between these artifacts and the non-grainy varieties of xenomorphic quartz (Figure 18). This is

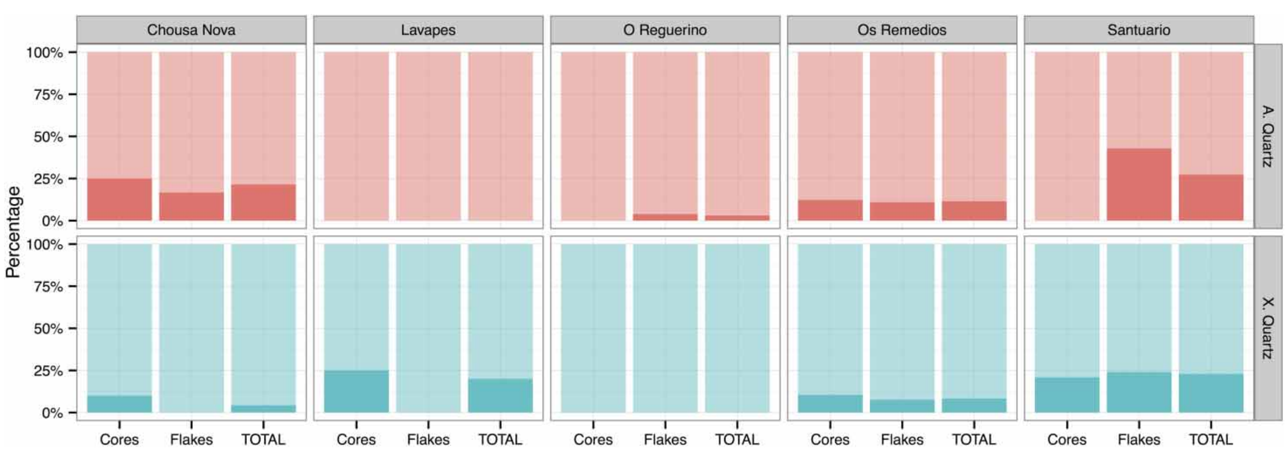

FIGURE 16. Presence (darker) of bipolar flakes and cores among the quartz assemblages.

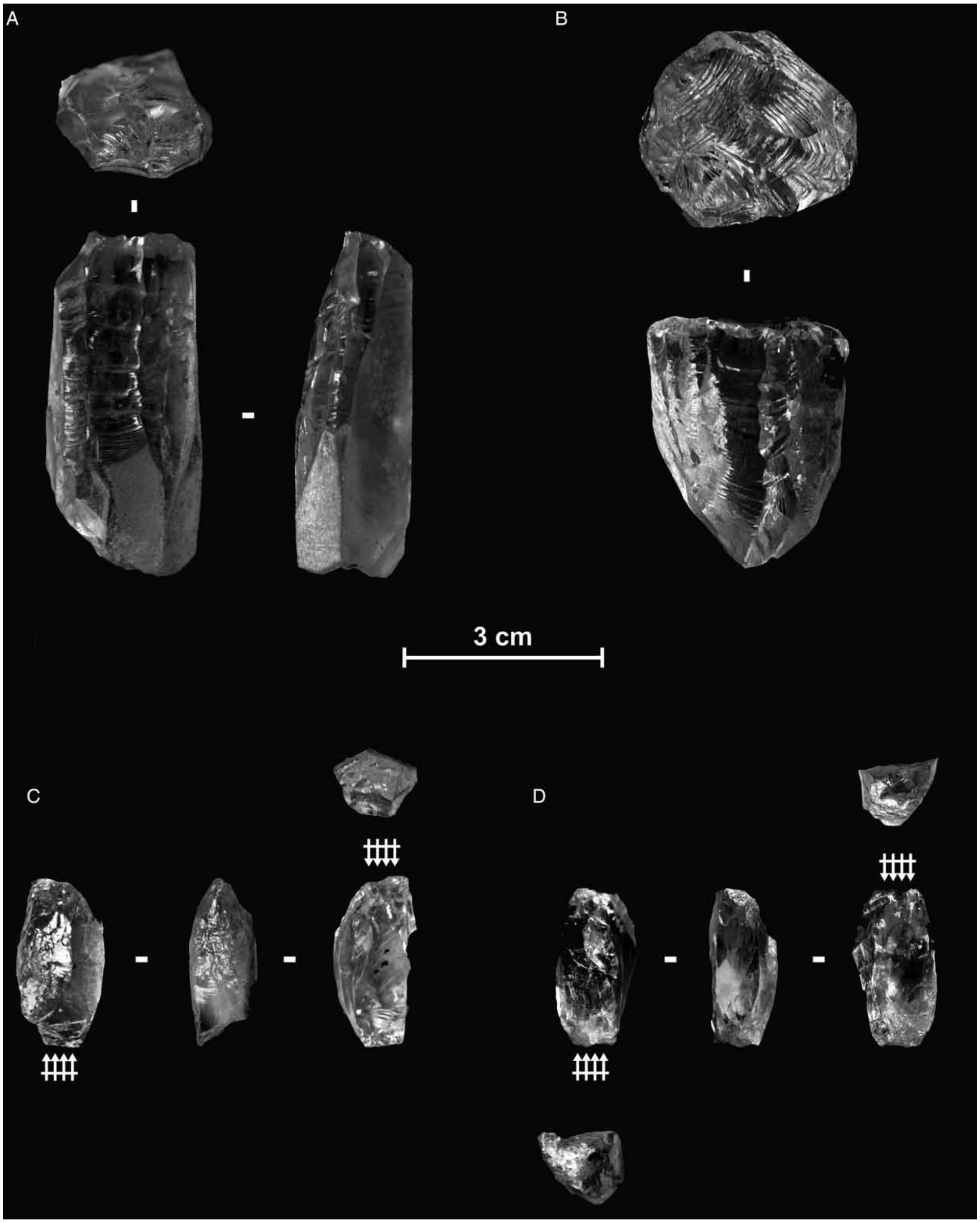

FIGURE 17. Microlaminar cores on automorphic quartz showing an oblique (A) and longitudinal (B) exploitation. Experimental (C) and archaeological (D) bipolar cores showing a longitudinal exploitation.

true for both simple retouched flakes and configured tools, although the latter have a major tendency of being associated with NN morphostructures, precisely those with a greater flaking quality and providing shaper and harder edges. On the contrary, the association between retouched tools and grainy varieties (YY and YN) is usually negative or, at best, neutral and it reflects the presence of few retouched artifacts made on fine-grained quartz that behaves as a good material during the knapping.

The scarcity of retouched artifacts might be interpreted as an interest for natural edges and also by a low necessity of its rejuvenation, given the relatively easy production of new ones. In fact, the modifications tend to be focused on the production of resistant angles for activities such as scraping.

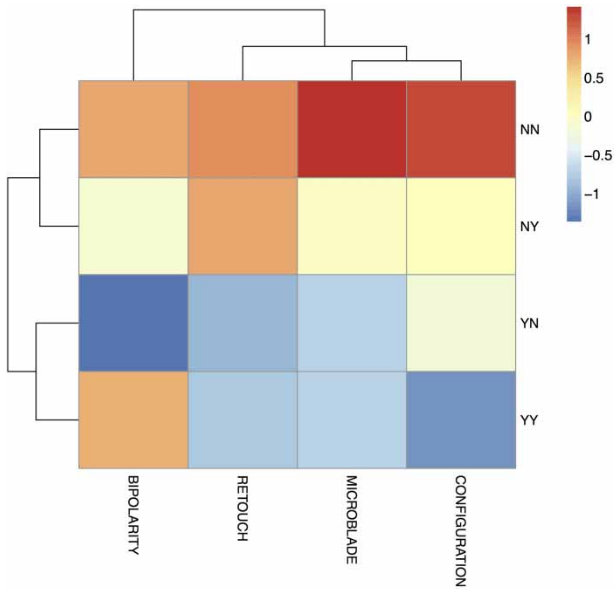

FIGURE 18. Heatmap showing the association and clustering between the different morphostructural groups of xenomorphic quartz and different characteristics.

Regarding the effects of the mechanical peculiarities of slate during its knapping, this has already been treated in detail elsewhere (Rodríguez-Rellán et al. 2011), so we will offer here a brief synthesis. As already noted, the characteristics of the metamorphic raw materials varied between the different sites: the slate exploited in the Morrazo Peninsula has a comparatively higher hardness and compactness and cleavage planes are not well developed, thus conferring a sub-conchoidal or even conchoidal fracture and relatively sharp and durable cutting edges to this material. As a result, these harder and compact varieties of slate can be knapped much in the same way as more standard materials and be used for cutting, scrapping and drilling.

On the contrary, the metamorphic raw material exploited in the Santuario is dominated by a gray slate whose main characteristic is a very marked slaty cleavage, causing a very irregular and splintery fracture, during which the material easily breaks up into "sheets" of regular thickness. *A priori*, such features would discard the knapping of this raw material, but –instead– it was successfully used for the manufacture of a specific item, arrowheads.

The experiments at arrow-making on the same raw material exploited in the Santuario (Rodríguez-Rellán et al. 2011) evidenced how the reduction of slate blanks by using either direct or indirect percussion and taking advantage of the slaty cleavage planes allowed a fast obtention of up to 30 sheets (from blanks between 500 and 1000 gr). These sheets, although without a useful edge, showed a straight delineation and a continuous thickness, thus making them a good blank for the shaping of projectiles, a task completed simply by a marginal retouching. The experimental shooting of these points (Figure 19) indicated that, despite a lower hardness, their effectiveness and resistance to impacts perfectly matched those of automorphic quartz or chalcedony. A further advantage laid on the significant saving of time, since the configuration phase on slate averaged 14 minutes, favorably compared to the 42′ on automorphic crystal and the 48′ on chalcedony (mainly due to the need of a more invasive retouch in the latter in order to reduce the thickness and balance the piece) (ibid).

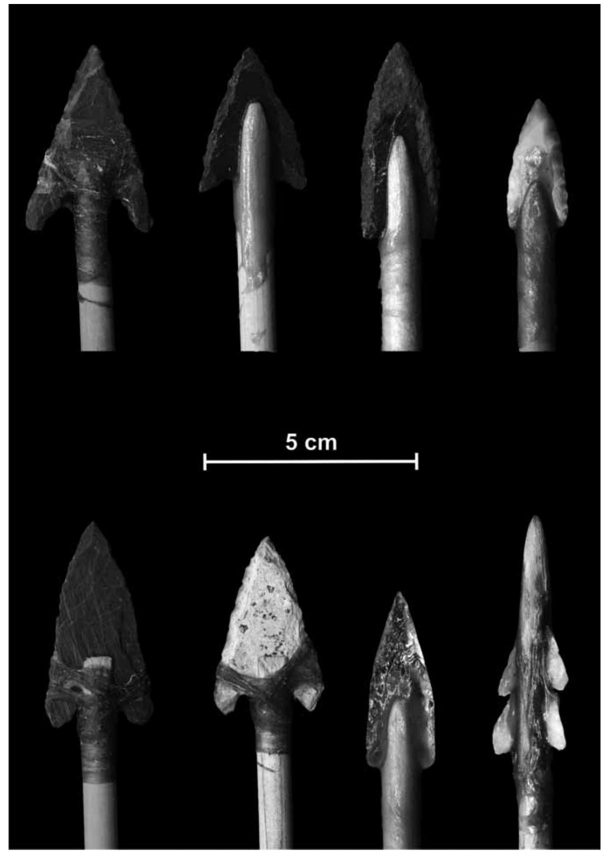

FIGURE 19. Experimental projectiles made on slate, local chalcedony, phyllite and automorphic and xenomorphic quartz.

The study of the slate assemblage of the Santuario suggests that the exploitation of this raw material was purposely focused on the obtaining of these straight, thinner sheets, subsequently used for manufacturing arrowheads. As in our experiments, the prehistoric knappers also took advantage of the cleavage planes during the reduction of the blanks, turning what *a priori* was a virtually insurmountable obstacle for the knapping into an advantage that saved much time and effort. Thus, as other authors have already stated (e.g. Eren et al. 2011), raw material "quality" should not automatically be considered as a determining or constraining factor, but as an opportunity to assess the – usually successful – adaptation of prehistoric knappers to the characteristics of available raw materials.

Conclusions

The study of five Neolithic and Bronze Age lithic assemblages from the NW of the Iberian Peninsula has shown an absolute preeminence of local non-cryptocrystalline raw materials, namely quartz and slate. These would have been accessible from both primary and secondary sources located in the immediate surroundings of the archaeological sites.

The analysis of the basic mechanical characteristics of these materials – not so well known among archaeologists as those of flint – led us to address the effects of anisotropy, cleavage or the morphostructure on the exploitation of quartz and slate. Anisotropy seems to have affected the knapping of some of the raw materials, especially automorphic quartz, hindering the flaking of crystals in certain directions, which would be feasible only by using specific techniques such as bipolar-on-anvil percussion. Meanwhile, cleavage planes have had a major effect during the knapping of slate and other metamorphic rocks, fractures occurring mainly along them. Still, this feature, rather than being a major obstacle for its exploitation, made easier the reduction of slate, obtaining sheets that saved much time and energy during the shaping of arrowheads in sites such as Santuario.

The analysis of the quartz morphostructure (presence of grain and flaws), in turn, was shown to be very useful for the understanding of the selection and flaking of this raw material, especially in its xenomorphic varieties. The Equotip analyses suggest that internal flaws would have played a major role during the knapping, reducing the homogeneity and continuity of raw material and, therefore, increasing the unpredictability of the knapping process and the risk of accidents. Despite this, it was observed in the archaeological collections that a non-grainy structure was a selective criterion rather than a lack of planes; thus, non-grainy raw material was preferentially sought for in the primary sources and also more intensively exploited. This preference for non-grainy morphostructures can also be seen in the xenomorphic quartz subjected to more complex strategies and to configuration processes. This choice was probably due to the fact that, even when having internal planes, it is a more homogeneous raw material and its knapping more controllable. Furthermore, it allowed obtaining sharper and resistant edges, a factor that seems to rank high among these prehistoric groups, given the dominant role of natural edges among the artifacts recovered.

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