Technological behaviors in Paleolithic foragers. Testing the role of resharpening in the assemblage organization

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A B S T R A C T
This paper describes the evaluation, based on archaeological materials, of the role that resharpening plays in the continuum of stone-tool reduction. We define a multi-evidence-based approach that combines use-wear intensity and location, traces that could be related to hafting and the distribution of mineral residue. By combining these methods, we have observed a minimum resharpening ratio of 52% in the selected end-scraper sample. If one takes into account ethnographically obtained information about end-scraper management, this result is an unexpectedly low value. Dynamics of mobility, technological organization and raw material availability causes high variability in the archaeological visibility and characteristics of lithic remains. Our results are in line with a technology organized wholly or partially on the basis of the expedition, in which tools are not curated for more than the time taken to complete the activity or the length of the occupation. Tools that were not exhausted were abandoned at the site, leading to recycling behaviors in periodic site reoccupations.

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1. Introduction

Measuring the degree of reduction in lithic tools has sparked the interest of many archaeologists during recent decades. Here, reduction is understood to be the continuous process of tool resharpening caused by the edge exhaustion while a given task is performed. The more reduced a tool is, the longer the usage time deduced, or the greater the intensity of the work. Thus, if we are able to measure reduction objectively and precisely, this will open the door to intra-site/multi-site and diachronic/synchronic comparisons between prehistoric groups. This will result in a robust approach to human behavior as related to several factors, including tool management, site occupation intensity, territorial mobility dynamics and raw material administration as a function of its abundance or scarcity.

Several researchers have focused their work on investigating ways to quantify reduction intensity and its implications. Their research takes different conceptual approaches to dealing with the question of reduction. Technological analyses (Dibble, 1984, 1987, 1995; Marwick, 2008), experimentally tested indexes (Hiscock and Attenbrow, 2002, 2003; Hiscock and Clarkson, 2005; Clarkson, 2002; Eren et al., 2005; Kuhn, 1990), and allometric relationships (Blades, 2003; Clarkson and Hiscock, 2011; Shott et al., 2000; Iovit¸, 2010; Eren, 2013; Eren et al., 2013) are the principal approaches to estimating reduction in archaeological and experimental samples. All of these approaches have emphasized the importance of reduction intensity as one of the characteristics that can provide the most useful information in the fields of lithic analysis and human behavior. All of them have the same strong initial hypothesis – that tool reduction is a function of time and usage. In order to be able to accept the measurements of reduction, it is necessary to confirm empirically that tools are reduced or resharpened during their functional life. It seems logical to think that maybe not all types of tools are sequentially reduced. Some kinds of highly standardized tools, or individual parts of composite implements (such as arrow armatures) can undergo only one shaping phase in which their functional morphology is defined. The sequence of the life cycle of these tools would be defined as (1) blank selection, (2) shaping, (3) use and (4) abandonment. In contrast, the sequence for tools that have suffered reduction must be (1) blank selection, (2) shaping, (3) use1, (4) resharpening, (5) use2, (6) resharpening, (7) abandonment, (8) (re)-selection, (9) (re)-use. In these specific cases, a tool...
is configured again and again, probably for the same use, so resharpening is an indicator of maintenance, not of retooling or a lateral change to a different cycle as proposed by Schiffer (1972).

We can derive from this that the basic cause of tool reduction is edge resharpening by retouching. An accumulation of resharpening events results in a progressive loss of mass and the morphological evolution of the tool. Identifying resharpening events in the lithic assemblage should be used as an initial test for deducing how reduction was present, and how much was present, in the technical behavior of prehistoric groups, or, at least, in the physical remains of the technology of the occupation we are studying.

The physical action of resharpening causes a wide range of modifications to lithic tools. It must be possible to observe the succession of working phases and resharpening events empirically in various ways — this cannot be just assumed a priori. In morphologically stable tool types, such as end-scrapers, the change in form after retouch is gradual, not abrupt. In these cases one expects that the functional retouched zone would be more or less the same after each resharpening event. Nonetheless, minimal morphological variations are accumulated after each modification, and this could create a final morphology that is slightly different from the initial one (e.g. Eren, 2013). These subtle modifications of the working edge must imply that functional evidence such as use-wear traces or residue preservation will not be completely superimposed after each resharpening phase. If this hypothesis is confirmed, then some kind of use-resharpening "stratigraphy" could be established through microscopic analysis. Initial use-wear traces should be partially removed by successive retouching, and different degrees of use-wear should be visible. Several functional analysts (Loebel, 2013; Jardon and Sacchi, 1994; Jardon, 2000) have used similar reasoning, but the authors have found no extensive documentation. The same reasoning could be applied to residue preservation and distribution. Organic residue is not commonly preserved at sites, but mineral residues such as iron oxides or the gums used in hide tanning or tool hafting are frequently documented. When these residues coat the tool, their distribution will be modified if resharpening occurs.

Resharpening and usage are not necessarily continuous over time, so tools did not have to be used immediately after retouching. It is well known in studies of lithic technology and mobility that stone tools were curated, or maintained and transported, to meet future necessities (Binford, 1977, 1978, 1979). Resharpening events and the moment of use could therefore be discontinuous in time, because some tools could be resharpened after one working phase to leave them ready for future use. When these tools are found in the archaeological record and no traces of the working event can be observed, they could be misinterpreted as unused tools. In these cases it is necessary to find indirect evidence of use in order to demonstrate that those tools have also been resharpened.

Recently, a modification of Eren's (Eren et al., 2005) ERP methodology for quantifying the mass lost in reduction has been proposed (Morales et al., in press). This new approach focused on the study of distally retouched tools such as end-scrapers. In order to apply this methodology systematically to the archaeological record, it is necessary to verify that this morphotype is systematically resharpened during its use-life. Ethnographic studies have demonstrated that end-scrapers are perhaps some of the most frequently resharpened tools in the lithic toolkit. We are therefore not dealing with an archaeological demonstration of rejuvenating end-scrapers, but with incidents of this technical behavior in specific archaeological samples. Taking into account the above working hypothesis, we have analyzed a very well preserved Late Upper Paleolithic stone tool assemblage in order to observe whether there is evidence of resharpening, and to establish the inferences that can be made from the reduction sequence with respect to site occupation.

2. Ethnographical remarks on the resharpening of scrapers

Even if ethnographical studies can't be directly transferred to Paleolithic studies they give an insight of concrete behavior of stone tool management. In this case, lithic tools used for scraping are well documented in living societies all over the world, and these are often related to woodworking. (Gould et al., 1971) or processing hides (e.g. Gallagher, 1977; Weedman, 2006; Mansur, 1986; Beyries, 2002; Beyries and Rots, 2008).

Our research into the archaeological evidence of functional rejuvenation is well supported by ethnographical studies of several of the above mentioned modern hiderscrapers. Ethiopian people use lithic scrapers as formal tools for hide processing. Resharpening has been reported as a technical behavior commonly used to rejuvenate edges when they become dull. Weedman reports a mean of eight resharpenings for each scraper during its use-life among the Gamo and a mean of 281 scrapes between resharpenings (Shott and Weedman, 2007). Among the Konso, hide-scrapers are resharpened regularly while processing a whole hide (Brandt and Weedman, 1997; Brandt, 1996). Among the Gurage people, resharpening behavior varies depending on the source, but it is also common. Gallagher (1977) reports a mean of 100 scrapes between resharpenings, while Clark and Kurashina (1981) note that resharpening occurs every 15/20 scrapes. All of them agree on the intensive use of scrapers, reporting that a mean of four to five scrapers are used during the processing of a cattle-sized hide.

Similar scraper use and management has been reported for the Athapaska people. Edge resharpening is performed regularly while processing a hide, especially during the hair removal phase. In contrast, during the softening process, resharpening rarely occurs (Beyries, 2002; Beyries and Rots, 2008). The same researchers report a case of unresharpened tools among the Chukchi people (Beyries and Rots, 2008). In this case, a broader toolkit of scraping tools is documented, and specialized scrapers are used during the different phases of hide processing. The Chukchi rarely resharpen the scrapers used.

Among the Tehuelche scrapers, periodic resharpening is also documented. Both the raw materials used — glass and chalcedony — are regularly resharpened when edges become dull (Casamiquela, 1978). In general, there is evidence of resharpening in all ethnographically observed scraping activities, not only in hiderscraping but also in woodscraping, as in the case of the Nganyatjarra tulas (Gould, 1971).

All of these ethnographical references are valuable in order to understand how scrapers are used, maintained and discarded in its economic context. Nevertheless, in order to understand the importance of tool curation and technological organization in Paleolithic foragers there is a great obstacle to using these ethnographic examples. All of the mentioned groups are sedentary farmers — they are no longer mobile hunter-gatherers (McCall, 2012). In their cases, the distance from and accessibility of, places where they can obtain raw materials is constant, provisioning is easily schedulable, and the storage of both unretouched and retouched tools is easy and unlimited. This gives them constant certainty of having tools ready for work when needed, and the provision efforts are clearly reduced. For highly mobile Paleolithic foragers, their mobility patterns, the constraints on raw material availability and the resulting technological organization must change the specific ways in which tools are managed. This must consequently be reflected in the tools’ versatility, suitability for carrying, and use-life prolongation. We therefore cannot take ethnographical resharpening patterns to be a direct analogy to the patterns of Paleolithic foragers. The stress agents suffered by the latter were different [i.e. (Torrence, 1983)], so it is reasonable to think that their technical and technological responses were different, too.
3. Material & methods

3.1. Materials

In order to evaluate the initial hypothesis from the archaeological record, a sample that fulfills some rigorous requirements in terms of preservation is required. We therefore looked for a sample from a modern and rigorous excavation in which the incidence of taphonomic alterations, such as burning, patina, concretion, edge rounding and trampling seems to have been very low. By being restrictive in the selection of the sample we can ensure that the preservation and observation use-wear is a priori good, and also avoid hydrochloric or ultrasonic washes and mechanical cleaning, which could affect residue preservation. With respect to the sample size we favored one that was significant but affordable, in order to accurately apply the multi-evidence approach methodology consisting in ochre distribution characterization and use-wear/hafting-wear analyses.

Taking into account these criteria, we selected the Late Upper Paleolithic lithic record recovered at level B of La Cativera rock-shelter, a Pleistocene–Holocene transition site in northeastern Iberia. La Cativera's level B is dated by AMS ¹⁴C to the early Boreal, between 10.3 and 9.6 kyrs BP in the 2-sigma calibration (Morales et al., 2013). Micromorphological studies (Angelucci, 2003) have revealed that the archaeological remains were quickly sealed by fine-grained slope sediments (see inline Supplementary Figure 1).

The excavation of this level has provided a lithic record consisting exclusively of regional flint and made up of 2406 pieces, 203 of which are retouched tools. Patina formation is almost inexistent, affecting only 7% of the assemblage and where present, is always in very incipient stages. Alterations due to burning are even less significant, affecting 3.3% of the assemblage. In most cases, fire damage is present on the pieces affected by patina formation. No ice damage or weathering has been documented. In preliminary functional approximations no water rounding has been observed, and very good edge preservation has been recorded. The conservation of mineral residues was also an important criterion in selecting the sample. The presence of ochre in the assemblage has been documented since the first studies (Fontanals, 2001) of the material from the site. Ochre remains have been recovered in form of burned centimetric fragments and also embedded in the surfaces of lithic tools. The presence of ochre at archaeological sites is well known, has been well studied and is usually related to preparing pigments, hide processing and the preparation of hafting mastic. No evidence of art has been found at La Cativera, but intense hide processing activities and systematic tool hafting are being documented. The relationship between ochre and lithic tools is therefore not casual, because there is a clear connection between tools and ochre-requiring activities such as hide processing (Philibert, 1993). The presence of ochre on lithic tools, and specifically, on end-scrapers has also been documented (Keeley, 1980), and especially in the European late Upper Paleolithic (Seronie-Vivien, 1986; de Beaune, 1989; Philibert, 1993).

Inline Supplementary Figure S1 can be found online at http://dx.doi.org/10.1016/j.jas.2014.05.025.

In northeastern Iberia, the late Upper Paleolithic is characterized by a reduced typological variability. The retouching pattern observed indicates that end-scrapers and backed elements are always the dominant groups, and together they usually amount to ca. 70–80% of the complete retouched assemblage. Taking this ratio into account, we selected the end-scraper assemblage from La Cativera's level B for analysis. This is made up of 129 pieces, 63% of the retouched tools.

3.2. Equipment

Four different microscopes were used for traceological and residue analysis: two Optical Light Microscopes and two Scanning Electron Microscopes. A μ-X-Ray diffractometer was also used. Technical characteristics of the equipment, sample preparation and image capture procedure are detailed in supplementary information.

4. Residue analyses and use-wear observation

4.1. Residue analyses

The macro- and microscopic analyses of the collection allowed us to identify evidence of reddish residues on 82 end-scrapers, approximately 64% of the total sample. A μ-XRD analysis gave the composition of the residue as iron oxide (Fe₂O₃) confirming that it can be attributed to hematite (Fig. 1). Aside from two imprints of
vegetal fibers preserved in the concretion no other organic residue has been documented.

Ochre distribution and preservation is not homogeneous throughout the entire sample. A high degree of variability was observed in the amount of residue present on each piece. This variability ranges from pieces which are clearly completely covered with ochre, to pieces on which there are isolated spots or small concentrations that are only visible with some magnification (Fig. 2). We are not currently able to assess whether this variability derives from functional differences or is just due to differences in preservation. On the basis of the distribution of the ochre embedded in the tool’s surface, three different categories or patterns have been established:

Pattern 1. Elements with residue concentrations on one surface or partially distributed on several surfaces.
Pattern 2. Pieces with ochre distributed over the whole of the surface.
Pattern 3. Pieces with a residual presence of ochre (isolated spots or particles) randomly distributed on one or more surfaces.

Of the end-scrappers with ochre, 70% fit the Pattern 2 distribution group (Fig. 3), conserving ochre more or less homogeneously distributed on the surface. Within this group, dorsal – ventral (≈38%) and dorsal – ventral – distal (≈25%) distributions are clearly dominant. It is therefore possible to say that there are two dominant groups that characterize the distribution patterns. One contains those pieces that are fully-covered (Pattern 2a in Fig. 2), and the other those pieces that are fully-covered with the exception of the functional (or active/retouched) surface (Pattern 2b in Fig. 2).
4.2. Use-wear observation

Firstly, we should comment on two aspects that affect the identification and analysis of use-wear formation in the La Cativera assemblage. On the one hand, the variety of chert from which the end-scrapers were made has differing responses in terms of light reflection, and as a result the quality of optical observations can differ from one piece to the next. On the other hand, the higher magnification power of the SEM has allowed us to identify lighter use-wear traces that were not observed with the OLM. As a result the level of documentation of tools observed with both SEM and OLM is higher than for those observed only with the OLM. The combination of different and complementary observation methods results in a higher level of information (Borel et al., 2014).

The use-wear analyses allowed us to identify wear traces on 105 end-scrapers, 82% of the total assemblage.

In this work we will focus on the activities performed using only the retouched part of the end-scrapers, dismissing those ones attributed to previous work carried out with the unretouched flakes. The type of work most documented was hide processing (95% of the cases), while woodworking (3 cases) and bone or antler working (2 cases) are very poorly represented, and need some clarification. Two of the tools had been used for woodworking when they were fully configured as end-scrapers. Another tool shows that it was first used on wood as an unretouched flake, and was later configured as an end-scaper used in hide processing. One of the two tools on which bone/antler wear was identified underwent a similar process. In this case, the end-scaper shaping retouch was superimposed on the traces of bone/antler working. The second tool in which bone/antler polish has been observed shows an alternation between bone microwear on one edge (pushing), and wear caused by hide working on the other, but the retouched end of the tool seems to be fresh.

Use-wear traces resulting from hide-working show a general appearance of abrasion without striation formation. Despite the different degrees of development, these surfaces are characterized by a process of attritional homogenization of the microrelief. Edges tend to be rounded and the contact surfaces smoothed. The texture observed with the OLM is slightly greasy and bright, while with the SEM it is coarse, and the micro- or cryptocrystalline texture of the rock is visible. In some cases it is possible to observe brighter, smoothened and isolated spots with the OLM. However, SEM observation of the same areas shows that these surfaces are not completely smooth (Fig. 4).

Wear characteristics indicates that the contact between the tool and the surface worked were marked by a moderately viscous interfacial layer that restricts the abrasion caused by the particles detached. We have documented these contact conditions when the hide is not completely dry through experiments (Olle, 2003; Vergés, 2003). Although the inner surface of the hide seems to be dry, the subcutaneous tissue may contain adipose cells and moisture that act as lubricants and prevent striation formation. In normal weather conditions (no rain and moderate humidity) the drying process starts just after skinning, being perceptible within a few minutes. However, if no other action is taken, hides can take several days to dry completely. This process varies depending on hide size and animal species. Taking these into account, the end-scrapers studied are used before the hide is completely dry. Despite the influence of the raw material, most of the variability observed in use-wear traces must be attributed to the different

Fig. 4. Example of hide-working use-wear traces. Top left, SEM secondary electron micrograph of scraping polish. Top right, enlarged detail of the same polish. Bottom left and right, equivalent OLM micrographs of the same zones observed at SEM. Magnification bar is equivalent for both SEM and OLM.
degrees of dryness of the hides as well as to the variation in the grease present in the interfacial layer.

Woodworking use-wear traces (Fig. 5) have rounded edges and rippled surfaces. The more highly polished zones show clear convexity. Their appearance is dense, bright and smooth and they display striations oriented in the direction of use. In the less affected zones, wear is only visible on the higher parts of the relief, while the lower parts remain unmodified.

In the bone/antler use-wear case (Fig. 6), the microrelief of the rock appears highly modified with little of the surface showing ripples, and the formation of flat plains. A characteristic is the formation of sub-parallel linear depressions oriented in the use direction. This association sometimes creates comet morphologies. Wear aspect is dense, bright, smooth and without striation. The boundaries are clear with abrupt ends.

4.3. Working cinematic

In all cases the edge was used transversally to the worked material. We have observed a pulling movement using the ventral face of the flake as a contact surface. Only in the 3 cases of wood and bone/antler working have pushing movements been observed.

Fig. 5. Example of wood-working use-wear traces. Top, OLM panoramic image showing wood-scraping polish on the functional edge of an endscraper. Middle, equivalent panoramic image from SEM secondary electron micrographs. Bottom left, detail of the OLM panorama. Bottom right, detail of the SEM panorama.
Taking into account the extension and penetration of polish in the ventral face of the tool, compared with our own experimental data (Vergés, 2003; Ollé, 2003) and similar data already published (Gutiérrez, 1996; Jardón, 2000), the analyzed end-scrapers used in hide processing shows high working angles of over 60°. A direct consequence of these working angles is the fact that the wear does not penetrate to the tool’s contact surface. In the most marked cases, the combination of high working angles and abrupt or obtuse edge delineations affects the ridges of the end-scraper retouch scars. Tools used for processing wood or bone/antler, however, show lower working angles.

4.5. Wear location and distribution

Use-wear traces caused by hide processing are always located in the retouched front edge and, sometimes, in the distal parts of the lateral edges. Given the high number of hide processing cases we have observed a high degree of variability within this pattern. In contrast, the wear distribution caused by wood and bone/antler working is focused exclusively on the middle part of the retouched edge, with a clearly delimited distribution. In wood processing cases, the width of wear is 1 mm and 3 mm respectively, with degraded penetration of 100 μm in one case and 500 μm in the other. In the only bone/antler case, the width is 1.5 mm with a very homogeneous penetration of 700 μm.

4.6. Use-wear intensity and working time

The process of developing polish is not regular or progressive, due to small fractures occurring as a brittle response to the strain (Ollé and Vergés, 2008, 2014), and also due to the total or partial resharping of the working edge. An assessment of the intensity or degree of deformation cannot be used as an unbiased method for comparing the duration of the work developed by different tools. Nevertheless, categorizing intensity could be useful for observing differences in development between different zones of the same tool.

In order to characterize the degree or intensity of deformation in the La Cativera’s end-scrapers, five different categories have been established and tools have been assigned to one of them (see distribution in Table 1; chi-square = 9.714, df = 4, p = 0.046).

1) Slight and discontinuous use-wear traces along the working edge. It provides weak criterions to establish which variables have taken part in the formation process. In some cases there is some doubt as to whether they can be identified as use-wear traces or just technical traces related to the retouch.
2) Light use-wear traces showing continuity along the working edge.
3) Well developed and continuous use-wear traces.
4) Well developed and continuous use-wear traces with clear edge rounding.
5) Well developed and continuous use-wear traces with dulled edges.

4.7. Hafting

The criterions used for identifying hafting traces have been based on those published by Rots (Rots, 2008, 2010) and on our own experimental series (Ollé, 2003; Vergés, 2003).

A total amount of 97 tools (75%) show some kind of evidence of hafting in the form of micro-chips or polishes that we have considered to be haft-related. We have defined three different degrees of development to classify hafting wears for each of the lateral edges of every single tool (see distribution in Table 2 and...
correspondence plot in Fig. 7; chi-square = 1.391, df = 3, p = 0.71):

1) Presence of micro-chip(s).
2) Presence of micro-chip(s) and slight polish.
3) Presence of micro-chip(s), highly polished, and dulled edge.

Other marks identified as resulting from hafting are abrasions and polishes on the dorsal ridges and elevated zones of the dorsal surface. Abrasions are characterized by matt appearance and a coarse texture, generated by an accumulation of microfractures. Polishes appear in form of flat plains with clear boundaries and abrupt ends. Close to the lateral edges, these deformations may be associated and/or superimposed (Fig. 8).

5. Evidence of resharpening

The distribution pattern of ochre embedded in tools, the use-wear distribution, and the hafting-wear identification has allowed us to observe and describe a set of criteria from which a technical process of resharpening is deduced. In some cases only one of these proofs is observed in tools, but in others, different proofs converge for the same tool.

5.1. Evidence from ochre

Of the ochre distributions, the totally-covered tools with the exception of the distal end, are characterized by a very specific diagnostic pattern stand out. It has been observed that, in most cases, retouch scars cut the ochre-covered surface, resulting in a new surface without any remaining ochre (Fig. 9). The end of the ochre distribution is abrupt, and not transitional. In some of these end-scrappers, it is possible to observe an even more complex pattern of ochre distribution. The dorsal and ventral surfaces and the more lateral and marginalized retouch scars, coinciding with the delineation change between the distal end and the edge of the tool, are still covered with ochre, but the central part of the retouched area has been uncovered. This fresh uncovered surface is clear evidence of resharpening.

5.2. Use-wear evidence

In comparison with experimental series (Ollé, 2003; Vergès, 2003; Jardón, 2000; Keeley, 1980; González and Ibáñez, 1994) “anomalous” use-wear distributions have been documented. These are characterized by discontinuous wear distributions or distributions within which the intensity varies (Fig. 10). Three categories of anomalous use-wear distributions have been established:

A) Use-wear discontinuity along the working edge with deformed and non deformed sections alternating. In some cases, this distribution is observed as small polished surfaces isolated along an unmodified edge.
B) The presence of use-wear in secondary zones of the working edge, while the most probable contact zones appear fresh.
C) Use-wear continuity along the working edge, but with differential intensities that cannot be explained by the delineation of the edge, its morphology or working movement.

The fact that these use-wear patterns can be identified implies the existence of partial or incomplete resharpening stages during use.

5.3. Evidence from hafting traces

Hafting traces have been compared with use-wear traces on the working edge in order to assess how they correspond in terms of intensity. When the intensities of the hafting-traces and the use-wear traces do not correspond, we then consider that this is due to the effect of resharpening. Clear differences between the active edge and hafting zone polish development can be observed in Fig. 11. Active edge shows none or minor polish but hafting zone displays a well developed and strong polish along the complete edge. These differences are reinforced by the fact that hide-working is an activity that generates strong polishes faster, implying that use-wear must be generated earlier and more intensively than hafting-wears.

Two different cases have been identified:

A) Presence of hafting-wear and absence of use-wear.
B) Lack of correlation between use-wear and hafting-wear. We can cautiously state that this has been only noted in cases of strong polish, dulled edge and chip presence in the haft section and (1) slight and discontinuous use-wear traces

Table 1
Distribution of use-wear intensity into the different categories.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Absolute</th>
<th>Relative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight and discontinuous</td>
<td>21</td>
<td>18.58</td>
</tr>
<tr>
<td>use-wear traces along the working edge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light use-wear traces</td>
<td>28</td>
<td>24.78</td>
</tr>
<tr>
<td>showing continuity along the working edge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well developed and continuous</td>
<td>28</td>
<td>24.78</td>
</tr>
<tr>
<td>use-wear traces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well developed and continuous</td>
<td>16</td>
<td>14.16</td>
</tr>
<tr>
<td>use-wear traces with a clear edge rounding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well developed and continuous</td>
<td>12</td>
<td>10.62</td>
</tr>
<tr>
<td>use-wear traces with dulled edges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ø Observable</td>
<td>8</td>
<td>7.08</td>
</tr>
<tr>
<td>Total</td>
<td>113</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2
Cross-table of hafting wears intensity correlation between right and left lateral edges.

<table>
<thead>
<tr>
<th>Right edge hafting intensity</th>
<th>Left edge hafting intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Micro-chip</td>
</tr>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Micro-chip</td>
<td>13</td>
</tr>
<tr>
<td>Micro-chip &amp; slight polish</td>
<td>3</td>
</tr>
<tr>
<td>Micro-chip &amp; polish &amp; dulled</td>
<td>1</td>
</tr>
<tr>
<td>Ø present</td>
<td>7</td>
</tr>
<tr>
<td>Ø Observable</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
</tr>
</tbody>
</table>
along the working edge or (2) slight use-wear traces showing continuity along the working edge. When it has not been possible to clearly establish differences between traces caused by retouching and/or intentional abrasion and hafting traces, care must be taken in making resharpening inferences from hafting traces. These modifications may have been made intentionally, in order to regularize the edge and prevent damage to the bonding elements of the haft.

6. The archaeological visibility of resharpening

The lithic assemblage studied presents a level of preservation of edges and mineral residues that has allowed us to follow a multi-evidence approach to identifying resharpening (identifications are shown in Table 3).

Through the functional analyses of active-edges, it has been possible to identify which of the end-scrapers have been resharpened (21.8%). Only those with several clearly observable use-wear generations were identified in this way.

Complementing functional analyses with observations of hafting wear increased the percentage of resharpened tools identified to 41.3% of the total. This method made it possible to identify resharpening in 19.5% of the tools that show no other characteristic feature (Table 4). Tools had to display wear deriving directly from hafting, which had to be cross-compared with functional evidence. If there is an absence of use-wear traces, or the degree to which these traces had developed does not correlate with the intensity of the hafting-wear traces, it is then very reasonable to assume that a resharpening phase occurred prior to the tool being abandoned (see Table 5).

Residue conservation introduces another type of direct evidence of resharpening from the ochre distribution. Thirty end-scrapers show a distribution pattern that fits with resharpening (Table 6) and in 10 of these (7.8%) ochre appears to be the only evidence of resharpening.

The total number of resharpened end-scrapers comprises 49.1% of the sample. This means that it has been possible to establish that at least half of the tools were used, maintained and used again. We have documented use-wear traces in 106 end-scrapers, 82% of the total. Taking this as a reference for the ratio of used to unused tools, we can say that the 45% of tools showing evidence of use had been maintained through resharpening. In addition, resharpening has been observed in 16 tools that show no evidence of use. There are therefore a total of 121 end-scrapers that may have been used, and 63 of those have been resharpened. This gives a final resharpened ratio of 52%. The ratio could be understood to be the Resharpening Index for the assemblage, in the knowing that it always represents the minimum percentage of tools resharpened. It is reasonable to suppose that some of the tools showing no evidence of use-wear may have been used and then retouched (or their use may have not developed any traces of use) and also that other hafting techniques didn't result in observable hafting wear.

![Fig. 7. Correspondence plot showing the co-occurrence relationship between different hafting wear developments in both edges of the tool.](image)
7. From resharpening to reduction and mobility patterns

The La Cativera’s end-scaper assemblage has yielded evidence of systematic resharpening in nearly half of the total number of tools studied. Although this might seem a high percentage, the fact is that ethnographical studies have shown that scrapers are continuously used and resharpened until they have been exhausted, and they are then discarded (Shott and Weedman, 2007; Brandt, 1996; Brandt and Weedman, 1997; Gallagher, 1977).

Although there is not a lot of quantitative information about end-scaper reduction, there are some comparable references that could be used to create a framework for the reduction carried out.
on the La Cativera tools. In Morales et al. (in press), the 3D-ERP method was developed to measure reduction in end-scrapers. In this study, the reduction carried out after the shaping phase was calculated, and this is equivalent to the reduction after the first use of a tool that had not been resharpened. The mean value obtained for the reduction intensity was $0.05 \pm 0.03$. La Cativera end-scrapers have a 3D-ERP value of $0.26 \pm 0.17$. The difference between these measurements clearly fits with the resharpening evidence documented by analyzing use-wear. That is to say, the tools have been reduced to a greater extent than the initial shaping performed on the 3D-ERP experimental series. A more extensively used measure of reduction — Kuhn’s geometric index or GIUR (Kuhn, 1990) — gives a very similar result. The value of GIUR for the experimental assemblage is $0.47 \pm 0.13$, while for the assemblage studied is $0.62 \pm 0.17$. Highly resharpened and reduced Gamo end-scrapers show a mean reduction value of 0.68 (Shott and Weedman, 2007). If we try to know which is the lowest GIUR sensitivity to end-scraper reduction — how much of the reduction could be attributed to resharpening events and how much to the shaping phase — GIUR value after shaping from Gamo end-scrapers is 0.53, being statistically similar to that provided by the only shaped experimental material ($0.47 \pm 0.13$). If we construct a relative GIUR scale for the end-scrapers reduction ranging from 0.47 to 0.68, the La Cativera end-scrapers are almost 30% less reduced than the Gamo ones. This scale has been constructed based on the mean values, and a significant number of individual measurements of reduction are higher or lower than these two extremes, but this is still a good illustration of the difference in the amounts of reduction (Fig. 12).

There are several possible ways of interpreting this apparent exhaustion of tools after non-intensive use. Firstly, it is possible that even more intensive SEM observations of all the specimens will yield a higher number of resharpening events due to the identification of use-wear traces that are lighter or purely testimonial. Additionally, very intensive resharpenings before discarding could have erased all the features of functional wear, and hafting techniques that did not result in wear may have been employed. Despite these known limitations, it is also obvious that there must be differences between the hide-scraper curating behavior of Paleolithic foragers and the known behavior of historic and sedentary hide-scrapers. Radically different settlement dynamics and mobility patterns should be reflected in the people’s technological organization (Bamforth, 1986; Andrefsky, 1991), and at the same time, should condition the formation processes that resulted in the archaeological record of lithic technology.

Since they are dependent on settlement and mobility, reduction intensity and tool use-time should vary from site to site, so one would expect to find varying values for reduction. Using Binford’s (1980) extremes of mobility patterns intuitively, reduction carried out at the base camp of a group with some level of logistical mobility should be high due to the re-use of a tool that is maintained for as long as is possible. On the contrary, reduction carried out at the base camp of a residential mobility group will depend exclusively on the work’s intensity and on the degree to which tools are curated. If a tool is used to its maximum potential, and is consequently transported from site to site, reduction values should be high by the time it is discarded. Nevertheless, when tools are used and discarded on the site and not incorporated into the toolkit and transported from site to site, reduction values should vary, and should probably be lower. In this case, the archaeological record would contain both exhausted tools and also tools that are still usable.

Our study case shows a degree of technological organization in which end-scrapers are used and reused while the group occupies...
the site and are probably abandoned when either the work or the occupation ends, independently of its remaining potential or maximum utility (Shott, 1996). In this way, end-scraper management could be defined as expedient, and this expediency allows us to make several inferences.

During the Late Upper Paleolithic, in the region in question there was no type of standardization in the blanks selected for shaping into end-scrapers. There is a great degree of variety in the flakes selected, and we found that cortical flakes, chunks, regularization flakes, regular blades and flakes produced during full-production had been used. This heterogeneity is also enforced by the high percentage of recycled pieces selected for shaping into end-scrapers. At other neighboring sites a Minimum Recycling Index of 20% has been observed (Vaquero et al., 2012a). In La Cativera we compute MRI using the double patina identification in both burned tools and non-fire patinated tools, and, despite the low sample, MRI is even higher, 30.77% (Table 7). This behavior must be related to well-established mobility routes that imply periodic reoccupation of the sites. Thus the certainty of the immediate availability of lithic raw material in form of discarded pieces from previous occupations reinforces the expedient behavior and the lack of curation of certain tool types.

The geological context in the region is characterized by the abundance of raw materials in primary outcrops drained by several rivers and channels which create an infinity of secondary catchment areas (Vaquero et al., 2012b; Soto et al., 2014). Thus the abundance of raw materials in the territory, the established mobility routes, and the periodic reoccupation of the sites all influence the technological organization (Andreosky, 1994), making it unnecessary to transport tools (Bamforth, 1986), at least for certain specific functional typologies.

The presence of end-scrapers resharpened before being abandoned indicates contradictory behavior in maintaining tools that are going to be discarded. Assuming cyclical reoccupation of the sites and the high indexes of recycling, it can be inferred that the users anticipated returning from the fact that these pieces are maintained and then not abandoned, but cached or kept at the site to meet future needs (Stevenson, 1982). The result is a mixed
picture in which tools are produced expeditiously for that situation and then cached as an “insurance-gear” for future use. Although technological organization is strongly related to mobility, a wide variety of scenarios is possible for the same mobility patterns (Sellet, 2013) depending on the resource management, functional activities and planned behavior in any given case.

8. Conclusions

Use-wear studies of lithic tools constitute a valid approach not only to reconstructing prehistoric work processes but also when the approach is behavioral or organizational. At many sites, lithic tools are the principal archaeological remains, if not the only ones, and must be studied from a wide range of approaches. The classic techno-typological approach usually provides very useful information about the periodicity and geographical distribution of prehistoric cultures, but technology clearly has the potential to provide more information. This potential is often untapped in favor of more simplistic explanations of variability.

Technological variability is cross-correlated with behavioral variability, but not always with cultural differences. Depending on the mobility patterns, raw material availability, resource exploitation and other factors, prehistoric groups could generate a variety of different archaeological records within the same cultural scenario. In La Cativera, tool abandonment in the early stages of reduction is a factor that conditioned the end-scrapers’ abundance in the archaeological record, and also its morphology. This implies larger tools, less extensive retouching and greater morphological heterogeneity. A change in this pattern, linked to raw material scarcity for instance, would transform the lithic record recovered. Abundance would decrease, tools would be transported, reduction

Table 3
Absolute value, relative value and cumulative percentages of the identification of resharpening depending on the kind of evidence.

<table>
<thead>
<tr>
<th>Resharpening case</th>
<th>Absolute</th>
<th>Relative</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use-wear</td>
<td>28</td>
<td>21.8</td>
<td>21.8</td>
</tr>
<tr>
<td>Hafting</td>
<td>25</td>
<td>19.5</td>
<td>41.3</td>
</tr>
<tr>
<td>Ochre exclusive</td>
<td>10</td>
<td>7.81</td>
<td>49.1</td>
</tr>
<tr>
<td>Ochre combined</td>
<td>31</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 4
Absolute and relative values of use-wear distribution.

<table>
<thead>
<tr>
<th>Use-wear</th>
<th>Normal distribution</th>
<th>A&amp;B distribution</th>
<th>C distribution</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>23</td>
<td>78</td>
<td>19</td>
<td>9</td>
</tr>
<tr>
<td>%</td>
<td>17.83</td>
<td>60.47</td>
<td>14.73</td>
<td>6.98</td>
</tr>
</tbody>
</table>

Table 5
Cross-table of hafting-use-wear intensity against use-wear intensity.

<table>
<thead>
<tr>
<th>Hafting-use-wear intensity</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Observable</th>
<th>Σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use-wear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>23</td>
<td>10</td>
<td>12</td>
<td>16</td>
<td>20</td>
<td>69</td>
<td>100</td>
</tr>
<tr>
<td>%</td>
<td>17.83</td>
<td>8.7</td>
<td>11.4</td>
<td>14.2</td>
<td>16.7</td>
<td>44.0</td>
<td>100</td>
</tr>
</tbody>
</table>

Fig. 11. SEM secondary electron mosaic images showing that the intensity at the end-scraper functional edge and the hafted left edge is clearly different. Top, panoramic view of both functional edge and left hafted edge. Dashed line indicates the active edge, and continuous line the hafted edge. Bottom left, generally fresh appearance of the functional edge showing some very low intensity use-wear traces between two resharpening retouches. Bottom middle, magnified detail of the low intensity use-wear traces. Bottom right, very high intensity hafting traces showing bifacial micro-chips, strong polish and dulled edge.
would be greater and therefore size would be smaller. Classificatory approaches sometimes attribute these variations to different lithic traditions – the microlithic “nail-like” end-scrapers versus the flake or laminar end-scrapers. Technological structure is anisotropic and changes depending on the conditions under which it is observed, this anisotropy is caused by dynamism in the economical structure of foragers. Static approaches can thus transform human responses into unreal cultural variations.

Table 6
Cross-table of ochre presence, functional use-wear distribution and hafting traces.

<table>
<thead>
<tr>
<th>Ochre</th>
<th>Ø Use-wear</th>
<th>Normal distribution</th>
<th>A&amp;B distribution</th>
<th>C distribution</th>
<th>Total Hafting traces</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>9</td>
<td>30</td>
<td>6</td>
<td>1</td>
<td>46</td>
</tr>
<tr>
<td>Yes</td>
<td>A 7</td>
<td>35</td>
<td>8</td>
<td>2</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>B 7</td>
<td>13</td>
<td>5</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>78</td>
<td>19</td>
<td>9</td>
<td>129</td>
</tr>
</tbody>
</table>

Fig. 12. Left, boxplot showing the GIUR values of the La Cativera sample compared with experimental and Gamo values. Right, histogram of the distribution of the La Cativera GIUR values, with the hypothetical distribution of a highly reduced assemblage shown shaded.

Acknowledgments

We are grateful to the staff of the Scientific and Technical Resources Service of Rovira i Virgili University for their help in the SEM observation process. This work has been developed within the framework of the Spanish MICINN projects CGL2012-38434-C03-03 and HAR2012-32548, and the Catalan AGAUR projects 2009SGR-188. J.I. Morales is a beneficiary of a predoctoral research fellowship (F1) from the AGAUR of Generalitat de Catalunya (FI-B2-2013). Authors also wants to strongly thank Michael Shott and Kathryn Weedman Arthur for their clarifications and comments about the Gamo endscraper, to Andreu Ollé, Maria Soto and Palmitra Saladí for their helpful comments, and to Dr. Richard Klein for their advice. The three anonymous referees clearly detect the weak points of the work and really help unraveling the previous version of the manuscript. Any existing mistake is author responsibility only.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jas.2014.05.025.

References


Table 7
Raw data for the Minimum Reduction Index calculation based on burned and patinated tools as proxy for the minimum estimate.

<table>
<thead>
<tr>
<th>Minimum Reduction Index</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endscrapers</td>
<td>129</td>
<td>100</td>
</tr>
<tr>
<td>Patinated</td>
<td>12</td>
<td>9.30</td>
</tr>
<tr>
<td>Burned</td>
<td>10</td>
<td>7.75</td>
</tr>
<tr>
<td>Patinated &amp; Burned</td>
<td>4</td>
<td>3.10</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>100</td>
</tr>
<tr>
<td>Recycled</td>
<td>8</td>
<td>6.20</td>
</tr>
<tr>
<td>MRI</td>
<td>30.77</td>
<td></td>
</tr>
</tbody>
</table>

Table 6
Cross-table of ochre presence, functional use-wear distribution and hafting traces.

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