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Lithics, landscapes & la Longue-durée – Curation & expediency as expressions of forager mobility

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A B S T R A C T

With the recognition that practically all archaeological sites are depositional composites unrelated to the activities of any contemporaneous group of individuals (i.e., palimpsests) and that forager adaptations are not 'site-specific' but rather landscape-scaled phenomena, statistical approaches designed to take these predicates into account have been developed over the past 20 years that depart from the traditional techno-typological systematics used for decades in much of Europe and the Levant. Based on artifact density and the frequency of retouched pieces scaled to the volume of sediment excavated in cave and rock shelter sites, and – for surface sites – the ratio of retouched artifacts to artifact totals scaled to unit area, they can potentially determine whether or not changes in mobility and land-use often assumed to have coincided with major evolutionary events (e.g., the Middle-Upper Paleolithic transition) actually occurred. Lithic artifact counts and densities from the cave of La Riera (Posada de Llanes, Asturias, Spain) are used here to illustrate the potential of the approach. Changes in artifact volumetric density are then compared with a radiocarbon summed probability curve using calibrated BP dates scaled against changes in oxygen isotope ratios in the GISP2 ice core. The intent is to determine to what extent macroclimatic change over the 30–10 ka cal BP interval compares with changes in the La Riera sequence.

1. Introduction – conceptual frameworks

Arising from dissatisfaction with the limitations of conventional techno-typological systematics (e.g., Bordes, 1961), novel approaches have been developed over the past 30 years to monitor aspects of human behavior that depart from the inductive culture historical paradigm employed for more than a century by Old World prehistorians working in 'deep time' (e.g., Bamforth, 1986; Dibble, 1987; Kelly, 1988; Barton, 1990; Kuhn, 1992; Shott, 1996; Bleed, 2001; Riel-Salvatore and Barton, 2004; Hiscock, 2007; Holdaway and Douglass, 2012). Retouched pieces figure prominently in both models but in radically different ways. In the culture history approach, retouched pieces are used to identify the mental templates according to which ancient peoples made stone tools, these tool forms persisting relatively unchanged throughout their use-lives and to the point at which they entered the archaeological record (e.g., Bordes, 1953; Hours et al., 1973). The reasoning behind this is the assertion that pattern in the Paleolithic is best (although not exclusively) apprehended by artifact typology. The form of retouched stone tools is interpreted as the tangible remains of technological and/or typological traditions held in common by identity conscious groups of people and transmitted from one generation to the next through a process of social learning. The intellectual mandate for this approach is French, and ultimately comes from André Leroi-Gourhan's *Le Geste et la Parole* (1964, 1965), which sought to invest the study of lithic technology with social agency. Loosely based on an essay by Marcel Mauss (1925) which established that technology was first and foremost a social process, Leroi-Gourhan proposed a unified approach to the study of the Paleolithic by uniting technology with social process, arguing that the long-term trajectory of social change can be examined by studying the evolution of technology, the latter accessible through the archaeological record.

The second approach takes a very different view. Beginning in the 1990s, this view of the causes of morphological variation began to be challenged, mostly by American and Australian workers. It first came under scrutiny about a decade earlier when Harold Dibble (1984) showed that the shapes of Middle Paleolithic side-scrapers probably represented no more than modal points along a continuum of morphological variation determined only by the size

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and shape of the original blank and the extent to which it had been modified by subsequent use. This argument was subsequently extended to the Upper Paleolithic, and then generalized to include most retouched tools (Sackett, 1981, 1988; Barton, 1991), thus largely discrediting the notion that there was much preconceived design specificity in their manufacture (Clark, 2009). In short, what the culture historians perceived to be discrete types might simply represent successive stages in the life histories of a single or a few generalized tools and/or minor alterations in form primarily determined by variations in blank morphology and retouch intensity (Dibble, 1987, 1995). The main consequence of this ‘paradigm shift’ is that retouch came to be seen as the unintended (and often unwanted) traces of efforts to extend the ‘use-life’ of lithics under conditions of scarcity through repeated modification of edges in order to wring the most utility out of a piece of stone that – when finally discarded – probably bore little resemblance to its original form (Barton, 1991; Dibble, 1995; Riel-Salvatore and Barton, 2004; Holdaway and Douglass, 2012); see also Tindale (1965) and Gould et al. (1970) for ethnographic examples). This is the perspective adopted here. Below we describe one such approach we believe to have wide applicability to chipped stone artifact assemblages and illustrate its power and generality by an analysis of a 14,000 year sequence from the cave site of La Riera (Figs. 1 and 2), located in Posada de Llanes, in the Principality of Asturias, north-coastal Spain (Clark and Richards, 1978; Straus et al., 1980, 1981; Straus, 1986; Straus and Clark. 1986).

2. Forager mobility and its material correlates

Forager mobility has been a topic of long-standing interest among Stone Age archaeologists in both hemispheres (e.g., Binford, 1980; Kelly, 1983, 1992; Grove, 2009, 2010; Kelly and Todd, 1988; see Kuhn et al. (2016) for a current appraisal). Depending upon the conceptual framework adopted, many different empirical referents have been proposed to distinguish among different ‘structural poses’ of foragers and there has been little consensus as to which are the most compelling because logical arguments have been made for all of them. Although everyone acknowledges that mobility was an important aspect of all forager adaptations, the issue has most often been addressed inductively, with little in the way of test implications. Explanations therefore tended to be little more than post-hoc accommodative arguments proposed after an analysis has been completed and lacking null and alternative hypotheses, expectations about pattern, and a deductive component that might allow us to determine which of several hypotheses is best supported empirically.

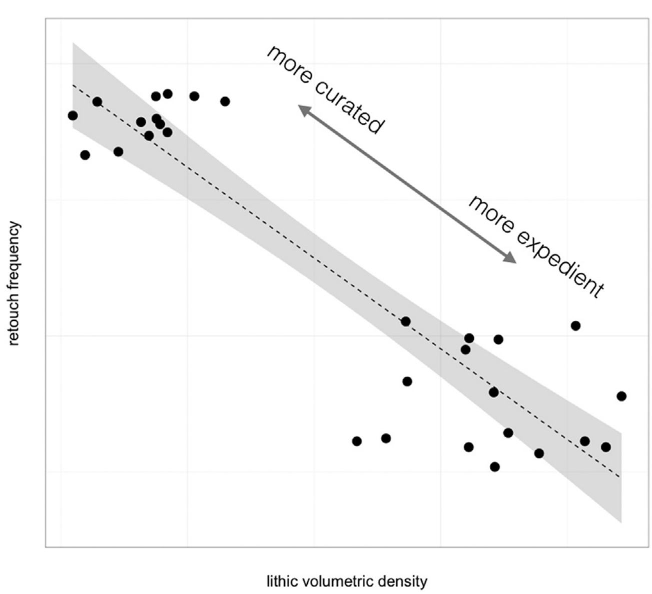

Fig. 1. The log of lithic volumetric density plotted against the log of the frequency of retouched pieces – a hypothetical example showing the distribution of curated assemblages (upper left) and expedient assemblages (lower right).

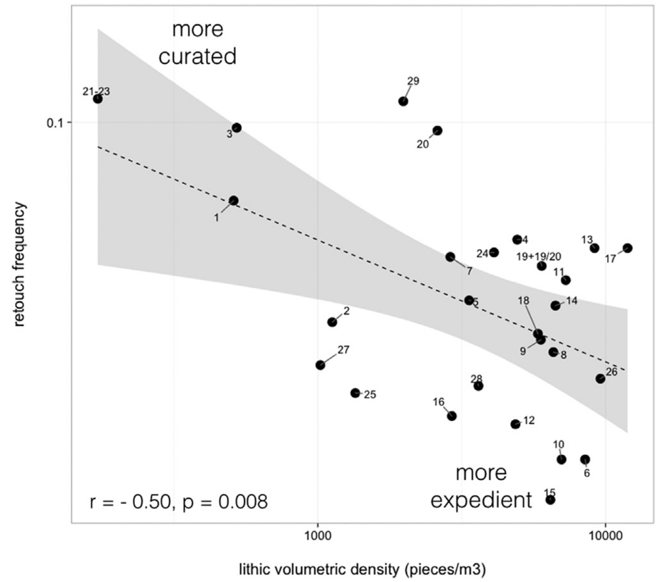

Fig. 2. La Riera – Lithic volumetric density plotted against the relative frequency of retouched pieces. The numbers refer to the levels in the site.

2.1. Research questions

Some of the more important research questions generated by an interest in forager mobility are: Did foragers move as a group, or did they deploy small bands of individuals from a residential base to acquire or process particular resources? How often did they move and under what circumstances? How were foragers distributed in the landscape? Did those distributions change seasonally, annually, at the scale of generations, centuries, over the long-term? What effect did climate change have on resource distributions and how did foragers respond to it? How did quality, package size, and availability of tool stone influence forager distributions? Most generally, how can we address these questions using the most common, and usually only, kind of artifact surviving from the remote past – lithics?

2.2. How does mobility affect the organization of lithic technology?

Ethnoarchaeological studies have identified multiple dimensions in the ways in which hunter-gatherers organize themselves and their activities in space and time (Bettinger, 1991; Kelly, 1995, 1992; Grove, 2009). In a landmark publication Binford (1980) distilled an important suite of these dimensions into a continuum with potentially significant impact on technological organization and how it is manifested in the archaeological record (see also Bamforth, 1986; Grove, 2010, 2009). Residentially mobile *foragers* tend to move camps and all group members from resource patch to resource patch within a territory over the course of each year, with relatively short-term stays at each campsite. Logistically organized *collectors* have one or a few central base camps, occupied for several weeks or even months during a year. A subset of the group travels out from the base camp in targeted forays to bring resources back to the full group at the base camp. While all hunter-gatherers practice central-place foraging to some degree, logistical organization typically involves resource forays of greater distances and sometimes lasting for several days.

Lithic technology was a fundamental element in the lives of prehistoric *Homo*, and stone was a critical resource essential to many daily activities. But using it also came with costs. A consequence of increases in distance and frequency of mobility was the need for hunter-gatherers to carry tool stone, exacting energy costs (i.e., the cost of transporting it) and opportunity costs (transporting stone meant fewer other resources could be carried to a camp where they could be consumed). The importance of lithic technology along with its costs to mobile foragers has implications for the generation of variation in the archaeological record discussed below.

2.3. Curated and expedient assemblages

In this paper we first assess the roles of curation and expediency as expressions of forager mobility and apply them to the La Riera sequence. The methodology used here was developed by Michael Barton and Julien Riel-Salvatore (Barton, 1998; Riel-Salvatore and Barton, 2004; Barton et al., 2011) and later modified by Barton and Alexandra Miller (Miller and Barton, 2008) to accommodate lithic samples from open sites. It arises from the behavioral ecology perspective adopted by some Anglophone workers over the past 15–20 years and uses the analysis of *whole assemblage behavioral indicators* (WABI) applied to landscape evolution and assemblage formation. WABI is a flexible approach that can be adapted to the analysis of both caves and open sites both within and between sites and across large geographic areas. Forager adaptations are never 'site specific' and La Riera is no exception. The second part of the analysis puts La Riera into the landscape perspective that constitutes the ultimate justification for the approach. Finally, we generate expectations for future research about the relationship between climate and forager settlement along the Cantabrian *montaña* – the narrow coastal plain where the site is situated and the mountain chain that lies immediately to the south of it. In places no more than 15 km wide, the coastal plain is dissected by short, swift, N/S trending rivers. The interfluves between them might have constituted economic territories for transhumant foragers travelling seasonally from the coast to the mountains (Straus, 1987). It is a reasonable but untested supposition that the 'structural poses' (Binford, 1980) of these bands might have changed in concert with the well-documented macroclimatic changes that marked the late Pleistocene and early Holocene.

3. Expectations about pattern in lithic assemblages

The conceptual approach that frames the research reported here proceeds from two fundamental assumptions that call into question the foundations of the culture history approach (e.g., Breuil, 1913; Peyrony, 1923). The first is simply that the conventional systematics that underlie the culture history approach are of limited utility in understanding past human behavior. Although Bordesian (or Bordian) methods imposed an order on previously idiosyncratic lithic typologies and led to replicable classifications of retouched stone artifacts, the behavioral implications of the resulting groups was never clear, largely subjective, assumed rather than demonstrated, and – since it lacked a deductive component – essentially untestable (Culley et al., 2013). If it is assumed a priori that those analytical units 'cleave nature at its joints', then patterns that cross-cut or are completely independent of them will be rendered analytically invisible. Moreover, the retouched artifacts upon which they are based usually account for only a small percentage of most lithic assemblages, lending them an interpretive significance out of proportion to their actual representation (Sackett, 1988, 1991). We argue that we must shift the emphasis from retouched pieces to whole lithic assemblages (see also Ahler (1989)), introduce a deductive component to research designs manifest in null and alternative hypotheses, generate test implications from them, and adopt statistical methods that allow for assessment of the probability that one or the other hypothesis is supported empirically (Holdaway and Douglass, 2012). Although largely confined to the Anglophone research traditions, this idea has had relatively little impact until recently on the research traditions of Latin Europe (but see, e.g., Villaverde et al., 1998; Bernabeu et al., 1999; Barton et al., 2002, 2004).

The second assumption is that the vast majority of retouched artifacts are the discarded remnants of casual tools and not the products of intentional design. While there are certainly exceptions (e.g., Solutrean points, microliths used in compound tools and weapons), artifacts that were the product of intentional design are rare relative to the Bordesian types recognized in typological systematics and in lithic assemblages in general (Hiscock, 2007). Similarly, the technological regularities upon which the *chaîne opératoire* approach is based (e.g., the 5–6 Levallois variants) are also explained by invoking technological traditions, with particular artifacts as intended goals, passed down from one generation to the next by social interaction (Bleed, 2001). We submit that the logic of inference subtending explanation of pattern regularities is *exactly the same* for both typology and technology, and subject to the same kinds of epistemic problems underscored by many workers for more than 30 years (see Binford and Sabloff (1982) for an early example).

Retouch in general is, therefore, argued to be unrelated to design specifications of any kind (with lithic artifacts hafted in compound weapons and tools the most notable exception). As noted above, retouch represents efforts to extend the use-life of lithics through repeated modification of edges (e.g., Bamforth, 1986; Dibble, 1995; Shott, 1996; Shott and Sillitoe, 2005). Put another way, the stone artifacts we recover pertain to those "landscapes of loss and discard" described by James Sackett – the exhausted remnants of tool stone reworked to various degrees under conditions of raw material scarcity (Sackett, 1991). If, however, raw material is plentiful and its sources known, there would be little need to engage in these economizing behaviors, and a low incidence of retouch when scaled to collection size or lithic density per unit volume would be expected. However central to the culture history approach, the implication is that identity consciousness 'writ small' in the form of stone tools is an illusion (e.g., Clark and Lindly, 1989; Clark, 1993, 1994, 2002, 2005).

3.1. Logistically organized Basecamps

As long ago as the mid-1970s Glynn Isaac (1976) suggested that modal site types were few and could be identified by the kinds of artifacts they contained. While simplistic from a modern perspective the basic idea was subsequently modified and carried forward in the work of Marks and Freidel (1977), Binford (1980, 1981), Kuhn (1991, 1994, 1995) and others (e.g., Bamforth, 1986) with the result that two major site types are generally recognized. Logistical base camps are sites with greater residential stability, relatively long site occupation ('long' in this case might be 2–3 weeks, but could extend for a month or more) and the larger groups typically found at aggregation sites where resource distributions are more predictable. Because the locations of raw material sources are known and individuals can make regular forays out from and back to a residential base, raw material procurement tends to be embedded in other activities and tool stone can be stockpiled at the site in anticipation of future needs. Logistical bases are marked by high lithic densities coupled with a low incidence of retouched pieces because resharpening is not needed to economize on locally abundant raw material. Hence, logistical bases typically have assemblages with lots of blanks, few retouched pieces, minimal core preparation and few exhausted cores. Assemblages with these characteristics are sometimes referred to as *expedient* (Nelson, 1991). They tend to be correlated with other evidence for increased sedentism (e.g., the accumulation of middens) accompanied by the provisioning of places rather than of mobile individuals (Parry and Kelly, 1987; Kuhn, 1992; Barton and Riel-Salvatore, 2014).

3.2. Short-term camps

Basecamps are juxtaposed with small and ephemeral overnight camps or limited activity stations. These represent the activities of small task groups deployed from a logistical base for specific purposes. Game lookouts and hunting camps are examples. Because these task groups might find themselves far from a logistical base with its reliable supply of tool stone, portable and versatile tool kits are of vital importance. Similar constraints apply to hunter-gatherers whose mobility strategies are characterized by regular residential moves across a series of short-term camps. Highly curated assemblages with low lithic densities, many retouched pieces, few blanks and small numbers of prepared core types that maximize cutting edge per unit volume would be expected. Such groups must rely on the things they can carry with them and those things must be lightweight, reliable, easily maintained, replaced or repaired, and polyvalent – capable of being adapted to a wide range of unforeseen circumstances. A higher incidence of retouched pieces relative to artifact totals would indicate these dimensions of greater residential mobility. One reviewer expressed these relationships succinctly:

> "… less retouch intensity = abundant raw material sources = higher LVD = reduced mobility = expediency = residential base. camps. It also follows that high retouch intensity = few blanks = low LVD = high mobility = curation = overnight camps."

Expectations about pattern in curated and expedient assemblages are summarized in Table 1.

If the logic of inference outlined above is secure, it follows that lithic volumetric density (LVD – the number of lithic artifacts per unit volume) and the relative frequency of retouched pieces should be inversely correlated with one another (Barton, 1998; Riel-Salvatore and Barton, 2004). Fig. 1 is a hypothetical example of an extremely well-segregated assemblage distribution. Curated assemblages are located towards the upper left, expedient ones towards the lower right. While seldom attained in practice (see Barton (1998) for a fortuitously clear-cut archaeological example), it provides a graphical assessment of the extent to which the relative frequency of retouched pieces is a function of the number of artifacts per unit volume and, by extension, the degree to which sites and levels are – *on average* – dominated by curated and expedient assemblages. That is, because prehistoric forager mobility and land-use strategies impact the assemblage-scale characteristics of lithic technology this way, lithic assemblages can serve as proxy measures of these mobility strategies.

At this juncture, it would be well to underscore the fact that, despite ethnographic descriptions of the range of mobility and land-use strategies of contemporary foragers, there is no way to actually *test* these expectations about pattern in the archaeological record using ethnographic data. Although 20th-century ethnoarchaeological research demonstrated the validity of our second assumption that retouch serves most often to resharpen the originally sharp, but subsequently worn, unretouched flakes preferred as 'tools', in no group of ethnohistorically-known hunter-gatherers were lithics still used as a primary technology at the time they were observed (e.g., steel projectile points among the Ju/'hoansi [!Kung] Bushmen (Wiessner, 1983), glass insulators used as cores by several groups of Australian aborigines (Gould et al., 1970); White and Thomas (1972) – for other ethnographic examples, see also Hiscock (2007); Holdaway and Douglass (2012); Parry and Kelly (1987); Shott and Sillitoe, 2005). Moreover, the ability of lithic assemblage characteristics to serve as proxies for hunter-gatherer land-use strategies is a consequence of interactions between human ecology and technology that play out over generations (or in the case of La Riera, millennia), aspects of adaptation that cannot be directly observed ethnohistorically.

This leaves two ways to test these expectations. One is by calculating LVD and retouch frequency for archaeological assemblages. A pioneering study by Parry and Kelly (1987) using New World data showed statistically significant correlations between lower mobility and a lower incidence of retouch, on the one hand, and higher mobility and more retouch, on the other. In analyses of nearly 200 Pleistocene assemblages from sites across Europe and Asia, in diverse depositional, geographic, and temporal contexts, LVD and retouch frequency consistently displayed a statistically significant negative correlation (Villaverde et al., 1998; Riel-Salvatore and Barton, 2004, 2007; Sandgathe, 2006; Clark, 2008; Riel-Salvatore et al., 2008; Barton et al., 2013; Kuhn, 2013).

Table 1
Material correlates of mobility.

A high incidence of retouch and low lithic volumetric density is consistent with:
• Less residential stability (= transient camps)
• Shorter duration of site occupation
• Smaller sites, local groups (= seasonal fission)
• Resources procured by moving the entire group (moves people to resources)
• No or few cores and little debitage
• Consistent with increased mobility and the provisioning of individuals
• Consistent with curated assemblages
A low incidence of retouch and high lithic volumetric density is consistent with:
• Greater residential stability (= base camps)
• Longer duration of site occupation
• Larger sites, local groups (= seasonal fusion)
• Resources procured by task groups deployed from residential bases (moves resources to people)
• Significant numbers of cores, unretouched flakes, blades
• Consistent with reduced mobility and the provisioning of places
• Consistent with expedient assemblages

The alternative way to evaluate these expectations is through computational modeling to simulate land-use strategies and technological practices of hunter-gatherers. In a recent study by Barton and Riel-Salvatore (Barton and Riel-Salvatore, 2013) such modeling experiments showed that the combination of mobility (i.e., logistical vs. residential mobility) and provisioning strategies (i.e., place vs. individual provisioning) is a significantly more important cause of variation in lithic density and retouch frequency for archaeological assemblages than other factors that could affect lithic technology like the availability of raw material and the tasks in which lithics were used. They also showed that archaeological assemblages produced under various combinations of mobility and provisioning strategies without exception displayed the expected negative relationship between lithic density and retouch frequency.

Table 2
La Riera- data summary.

Level	Total Lithics	Volume Exc'd. cubic m	Lithic density	Total Ret'd.	Ret'd. Freq.	Bld'ts.	Ret'd. Bld'ts.	Ret'd Bld'ts. freq.	Mean modeled age BP
29	595	0.300	1983	64	0.108	55	6	0.010	9595
28	832	0.230	3617	32	0.038	39	20	0.024	10,339
27	2553	2.500	1021	105	0.041	65	42	0.016	11,723
26	1343	0.140	9593	52	0.039	23	10	0.007	12,756
25	54	0.040	1350	2	0.037	1	0	0.000	12,977
24	3277	0.800	4096	202	0.062	228	107	0.033	13,271
21–23	558	3.250	172	61	0.109	69	11	0.020	14,944
20	2085	0.800	2606	203	0.097	67	136	0.065	16,855
19 + 19/20	5040	0.840	6000	297	0.059	625	193	0.038	18,665
18	4889	0.840	5820	225	0.046	343	163	0.033	19,563
17	2384	0.200	11,920	151	0.063	240	110	0.046	20,196
16	5262	1.800	2923	181	0.034	204	52	0.010	20,666
15	3087	0.480	6431	76	0.025	67	14	0.005	21,361
14	6160	0.920	6696	316	0.051	300	19	0.003	21,589
13	824	0.090	9156	52	0.063	21	3	0.004	21,823
12	389	0.080	4863	13	0.033	23	0	0.000	22,195
11	1164	0.160	7275	65	0.056	30	3	0.003	22,683
10	2460	0.350	7029	71	0.029	45	0	0.000	22,913
9	2384	0.400	5960	107	0.045	73	1	0.000	23,024
8	2700	0.410	6585	116	0.043	83	8	0.003	23,405
7	2455	0.850	2888	149	0.061	117	13	0.005	23,630
6	1359	0.160	8494	39	0.029	33	3	0.002	23,778
5	1309	0.390	3356	68	0.052	104	15	0.011	23,928
4	1628	0.330	4933	106	0.065	144	18	0.011	24,088
3	450	0.860	523	44	0.098	36	2	0.004	24,231
2	146	0.130	1123	7	0.048	19	1	0.007	24,395
1	765	1.500	510	57	0.075	57	3	0.004	24,805
Totals	56,152	18.850		2861		3111	953		

4. Methods

The initial WABI analyses reported here require only three statistics widely available in many site reports. These are (1) the volume of sediment excavated by analytical unit (e.g., level, square, site depending on the scale of analysis), (2) the total number of lithic artifacts, and (3) the relative frequency of retouched pieces. As noted above, comparing LVD (= total lithics recovered/volume of sediment excavated by excavation level) and retouch frequency (= total retouched lithics/total lithics for each level) provides an important proxy for land-use and mobility strategies employed by the foragers that occupied La Riera. The results of these analyses are shown in Figs. 2–4.

We also examine the bladelet component of lithic assemblages (= total retouched bladelets/total bladelets for each level) for evidence of manufacture vs. in-field maintenance of compound hunting weapons that are key components of late Pleistocene resource acquisition technologies (Neeley and Barton, 1994; Barton et al., 2013). Bladelet assemblages dominated by retouched (mainly backed) pieces are indicative of the maintenance of compound weapons in which the disposable lithic components are replaced and discarded when they break, fall out of the haft and are lost, or become dull. Conversely, bladelet assemblages dominated by discarded unretouched pieces are more indicative of the manufacture of compound weapons. Compound manufacture is more likely to have occurred at base camps, while in-field maintenance tends to be associated with short-term hunting camps (Bleed, 1986). Results of analysis of bladelets is shown in Fig. 4b. The raw data used in the LVD, retouch, and bladelet analyses are shown in Table 2.

The numerous radiocarbon dates from La Riera allow us to apply new statistical methods to create detailed, calibrated age vs. depth models and to calculate summed probability density curves for all dates combined. We follow methods described by Parnell and colleagues (2011, 2008) that use iterative Markov Chain Monte Carlo simulation to estimate populations of Bayesian posterior probabilities for ages based on the uncalibrated radiocarbon date priors. Table 3 gives the original, uncalibrated radiocarbon dates for the site, the calibrated dates, and summary values from the age-depth model. Fig. 5 shows the probability curves for all calibrated dates and the age-depth model, as well as the age-depth model for the site. The central line of the graph is the mean age in calibrated years BP for each depth in meters below surface. The grey band around the mean is the 95% confidence interval for the model. Associated excavation levels, from which artifact counts were drawn, are shown on the y-axis. The age-depth model allowed a coherent series of calibrated age estimates to be assigned to each level, regardless of whether or not datable material was recovered from the level (Fig. 5, Table 2). It also allowed us to estimate sedimentation rates (Table 3) and, by applying this to the LVD values, to determine rates for the accumulation of discarded lithic artifacts and debris.

Table 3
La Riera Radiocarbon Dates. Uncalibrated dates, 95% CI for calibrated date ranges, and modeled mean sedimentation rate for each dated level.

Level	Lab. No.	Material dated	Uncalibrated date BP	Calibrated 95% Cl date BP	Mean modeled sedimentation rate (m^3/1 ka)
29 top	GaK-3046	charcoal	6500 ± 200	6941–7743	0.069
29	GaK-2909	charcoal	8650 ± 300	8996–10,439	
				10,455–10,491	
27 upper	BM-1494	bone	10,630 ± 120	12,164–12,209	0.149
				12,231–12,354	
				12,370–12,733	
27 lower	UCR-1275D	bone	12,270 ± 400	13,389–15,594	
27 lower	GaK-6985	charcoal	14,760 ± 400	16,967–18,808	
24	GaK-6982	charcoal	10,890 ± 430	11,408–11,438	0.194
				11,475–11,554	
				11,598–13,565	
23	Ly-1646	bone	10,340 ± 560	10,519–13,206	0.133
23	UCR-1274D	bone	12,620 ± 300	13,939–15831	
20	Ly-1645	bone	12,360 ± 670	13,008–16,384	0.061
20	UCR-1273D	bone	9090 ± 570	8793–8828	
				8867–8882	
				8899–8911	
				8975–11,846	
				11,860–11,960	
20	GaK-6980	charcoal	17,160 ± 440	19,684–21,816	
19	Q-2116	charcoal	15,230 ± 300	17,813–19,107	0.065
19	Q-2010	charcoal	15,520 ± 350	18,003–19,571	
19	GaK-6448	charcoal	16,420 ± 430	18,848–20,788	
17	GaK-6445	charcoal	16,900 ± 200	19,924–20,875	0.177
17	GaK-6444	charcoal	17,070 ± 230	20,030–21,190	
16	GaK-6983	charcoal	18,200 ± 610	20,550–23,363	0.273
15	GaK-6449	charcoal	15,600 ± 570	17,639–20,146	0.094
15	UCR-1272A	bone	17,225 ± 350	19,981–21,719	
14	UCR-1271A	bone	15,690 ± 310	18,311–19,674	0.178
12	GaK-6446	charcoal	17,210 ± 350	19,954–21,712	0.064
10	GaK-6447	charcoal	19,820 ± 390	22,927–24,862	0.228
8	GaK-6450	charcoal	15,860 ± 330	18,498–19934	0.152
8	GaK-6981	charcoal	20,690 ± 810	23,001–26,491	
4	GaK-6984	charcoal	20,970 ± 620	23,757–26,435	0.415
1	UCR-1270A	bone	19,620 ± 390	22,684–24,471	0.445
1	Ly-1783	bone	20,360 ± 450	23,498–25,595	
1	BM-1739	bone	20,860 ± 410	24,203–25,871	

Summed probability densities of the calibrated radiocarbon age estimates have been used as proxies to estimate prehistoric occupation intensity and regional demography (Shennan et al., 2013; Contreras and Meadows, 2014; Crombé and Robinson, 2014; Timpson et al., 2014; Bernabeu et al., 2016). Beyond a desire to date as much of the sequence as possible, there was no bias in the collection of samples for dating during the excavation (Straus and Clark, 1986, pp. 19–23), so the frequency of dates through the site sequence is primarily a function of the availability of datable material. Hence, the conceptual bases of prior work can be applied to the series of La Riera radiocarbon dates so that the summed probability curve (Fig. 4c) provides an estimate of occupational intensity through time that is independent of artifactual evidence.

5. The La Riera site and sequence

La Riera lies in a small cul-de-sac valley on the north coast of Spain in the drainage of the Río Calabres, a minor tributary of the Río Bedón in the Principality of Asturias about equidistant from the regional capitals of Santander and Oviedo (Clark and Richards 1978) (Figs. 6 and 7). There are 10 sites in close proximity to La Riera, a fact of some significance to which we will return below (Fig. 7) (Clark and Straus, 1977). Excavated to modern standards, La Riera contains 29 levels spanning the entire Upper Paleolithic and Mesolithic and is dated from >20,000 to 6500 years ago. Assigned on the basis of archaeological 'type fossils', Level 1 is Aurignacian or Gravettian, Levels 2–17 are Solutrean, Levels 18–20 are Lower Magdalenian (i.e., they lack harpoons), Levels 21–26 are Upper Magdalenian, Level 27 is either late Magdalenian or Azilian, Level 28 is Azilian, and Level 29 is Asturian. Again, LVD allows us to assess the extent to which the relative frequency of retouched pieces is a function of the number of artifacts per unit volume. Figs. 2 and 3 show lithic volumetric density relative to the frequency of

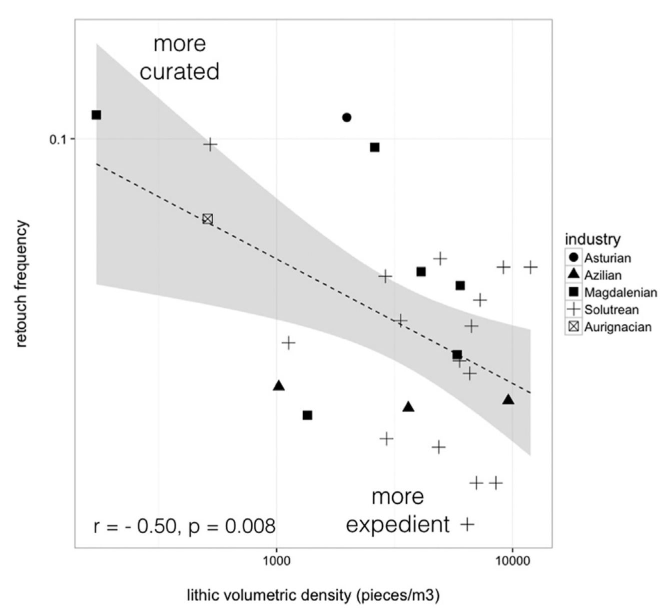

Fig. 3. La Riera – Lithic volumetric density plotted against the relative frequency of retouched pieces. The symbols refer to the analytical units or industries generally recognized by conventional systematics.

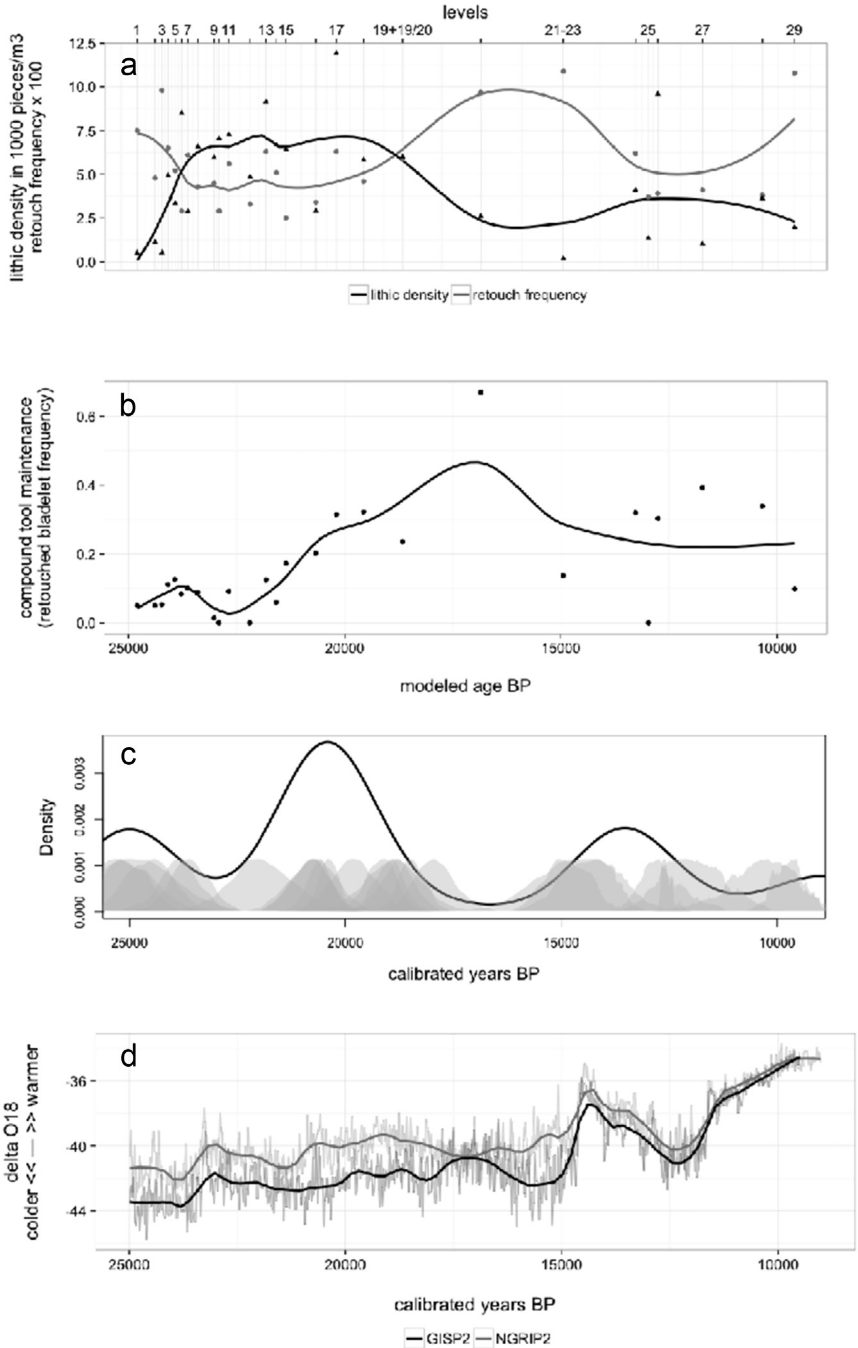

Fig. 4. La Riera assemblages in temporal and environmental context. (a) Lithic volumetric density and retouch frequency (x 100) plotted against modeled age of excavation level (see text, Table 4). Points are raw assemblage values and curves are LOESS smoothed trends. (b) retouched bladelets (including backed)/all bladelets (retouched and unretouched) plotted against modeled age. (c) Black line is summed probability curve of all calibrated ^{14}C dates; grey polygons are probability distributions for the estimated ages of individual calibrated ^{14}C dates. (d) Values from portions of the GISP2 and NGRIP ice cores with new recalibrated dates (Rasmussen et al., 2008); $\Delta^{18}O$ values (fine, light curve) and LOESS smoothed trendline (heavier, darker curve) are proportional to paleotemperatures and glacial ice volume.

retouched pieces by level (Fig. 2), and by traditional (i.e., typology-based) industries (Fig. 3); variation in LVD and retouch frequency though time, and in relation to late Pleistocene and early Holocene climate change of the are shown in Fig. 4a. As expected, LVD and retouch frequency are significantly negatively correlated (Fig. 2). It is also interesting to note that both the original study and the WABI analysis presented here identify patterns that are roughly consilient with each other and that either cross-cut or are independent of the conventional typological assignments for each unit (Clark et al., 1986; Straus et al., 1986).

6. Forager mobility at La Riera

Keeping in mind that La Riera did not exist in isolation from other sites and that the 'structural pose' of the site probably changed over time, what do we make of this so far as forager mobility patterns are concerned? Several distinct patterns are apparent. First, and as expected, the log correlation coefficients of the scatterplots (lower left) depart from the ideal pattern although, depending on the level of significance chosen, the probability of getting a correlation coefficient of − 0.50 is very low ($p = 0.008$).

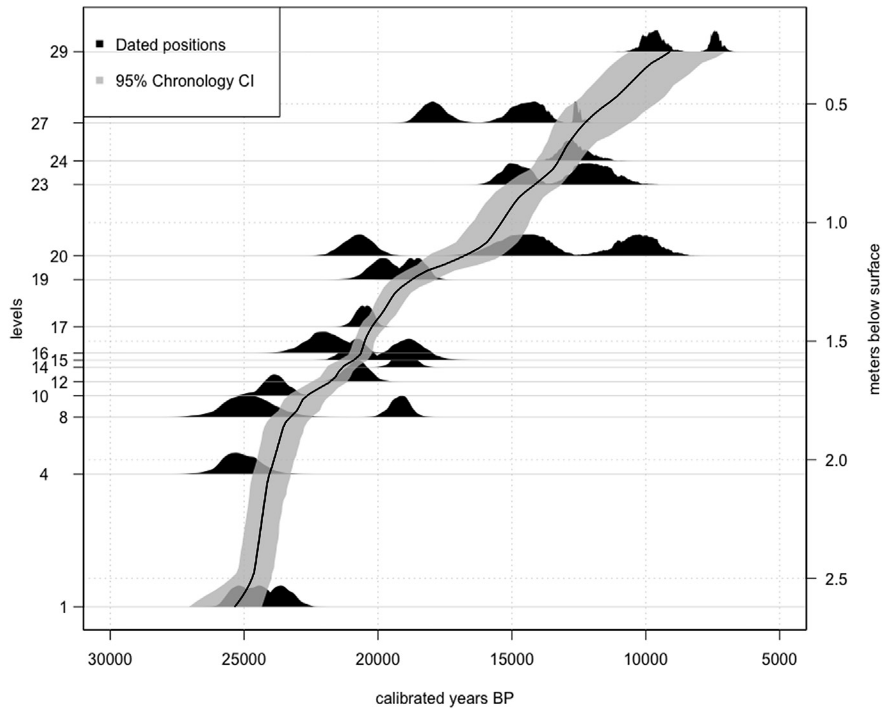

Fig. 5. Age-depth model for La Riera stratigraphy based on methods described by Parnell and colleagues (2008, 2011). Excavation levels shown on left side; depths below surface shown on right side; x-axis indicates modeled calibrated age. Black polygons show the probability distributions for the calibrated age of individual ^{14}C dates. Continuous grey band extending from bottom to top shows 95% confidence interval of modeled calibrated age at each depth; solid line in the middle of the band is the mean age at each depth.

Second, the scatter plots indicate that the nature of human occupation at La Riera varied over its long history, but tended more toward the logistical base end of the continuum than it did toward the short-term camp. Most of the levels are concentrated in the right lower part of the graph (Figs. 2 and 3). Third, La Riera is mostly a 'Solutrean' site but no particular significance can be attached to that fact. The Solutrean levels are interspersed amongst those of other units with respect to retouch frequency and lithic density.

Only four of the levels fall in the highly curated part of the graph (upper quartile for retouch frequency and lower quartile for LVD) but, interestingly, they represent four different typologically-defined industries (Aurignacian [Lev. 1], Solutrean [Lev. 3], Magdalenian [Levs. 21–23], Asturian [Lev. 29]). This indicates occupations characterized by ephemeral campsites, a finding in good agreement with the interpretations of the excavators (Straus and Clark, 1986, pp. 75–187). This is especially clear in the case of Level 1, a thin occupation scatter surrounding two small, informal hearths.

Most of the levels fall into the expedient quadrant of the graph, including most (but not all) classified typologically as Solutrean and half classified as Magdalenian or Azilian (Fig. 3). Even the most heavily curated levels have higher retouch frequencies and lower lithic densities than found in assemblages dated to the last Interglacial (MIS 5) and early Glacial (MIS 4) in Europe where retouch frequencies can exceed 0.50 and lithic densities can fall below 10/m^3 (Riel-Salvatore and Barton, 2004; Riel-Salvatore et al., 2008; Barton et al., 2011; Barton and Riel-Salvatore, 2012). At La Riera, only two assemblages have retouch frequencies that slightly exceed 0.10 and three have lithic densities below 1000/m^3, with no densities below 100/m^3 (Table 2). The La Riera case is typical for the European Pleniglacial, however, where retouch frequency in most assemblages studied are below 0.20 (Barton et al., 2011).

7. Other lines of evidence

How do the results of the analysis – restricted to the lithics – compare with other kinds of evidence for behavioral and paleoclimatic change at the site? To try to determine whether, and/or to what extent these lines of evidence supported or called into question the results of the LVD analysis, we re-examined the published accounts of the paleontology (mammals, birds), malacology, ichthyology, sedimentology, speleothems, palynology and macrobotanical remains that resulted from the 1976–9 excavations. The mammal faunas were particularly informative; NR, MNI counts; anatomical parts represented, degree of fragmentation, breakage patterns, age, sex and metric data by levels were recorded (Altuna, 1986). We also looked at the worked bone and antler assemblages. While much useful information resulted from these studies in respect of seasonality, intensity of faunal exploitation and dietary stress, strong correlations with the LVD analysis proved to be elusive. Consistent with the results presented here, however, certain levels (6–10) did indicate a relatively intense human presence in the cave when compared to the rest of the sequence. Despite climatic fluctuations and changes in the intensity of exploitation, red deer and ibex dominated throughout the sequence. Other species were rare. Although common on the plains of Aquitaine and present in Franco-Cantabrian art, an unambiguous cold-climate indicator, reindeer, was almost completely absent (7 bones in Levs. 24–21), as they are in all north Spanish sites. An open-country species, reindeer never colonized the Iberian Peninsula in significant numbers, probably because the mountainous terrain of the Cordillera Cantábrica proved an insurmountable barrier to range extension and they were unable to cross it to reach the more favorable environments of the Meseta del Norte.

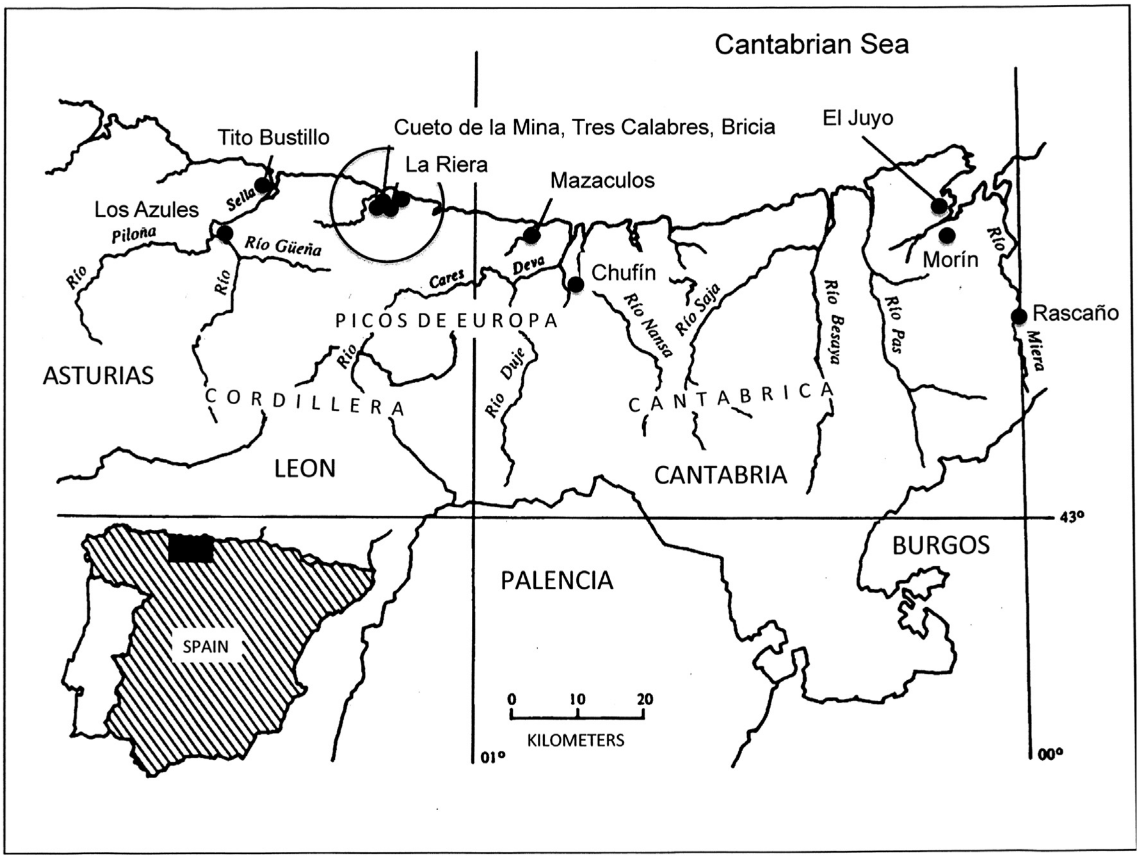

Fig. 6. Map of the Principality of Asturias showing the location of La Riera and some other important Upper Paleolithic and Mesolithic sites.

8. La Riera in context

It is important to keep in mind that the individual assemblages at La Riera and the excavation levels from which they were derived represent *time averaged palimpsests* that can represent millennia (Figs. 4 and 5) and the debris from numerous individual occupations. Even the lowest density assemblage (levels 21–23) produced 172 lithics/m^3 (Table 2). The distribution of assemblages along the curated-expedient axis in Figs. 2 and 3, then, should be taken to represent variation in the relative contribution of artifacts from base camp occupations and short-term camps within each palimpsest. Fig. 4 shows the La Riera assemblages in temporal and climatic context. Points mark values for individual assemblages in 4a and 4b, while the lines represent LOESS smoothed trends that show broad shifts in the character of occupation at the site. Levels 3–19 show generally higher lithic densities and lower retouch frequencies, indicating assemblages dominated by debris from logistical base camp occupations. Within this interval are the lowest retouched bladelet frequencies, indicating compound tool manufacture rather than in-field maintenance. This interval also includes the peak of the summed probability radiocarbon curve, suggesting the most intensive accumulation of datable materials at the site. Finally, the highest values for bone breakage for marrow extraction (Clark and Straus, 1986, p. 359) are found in this interval, in agreement with a dominance of longer-term base camp occupations.

Conversely, levels 20–23 have high retouch frequencies and low LVD, indicating that a larger proportion of the artifacts in these levels derived from the accumulation of the sparse artifact discards at ephemeral camps. Higher frequencies of discarded bladelets are retouched (>60% in levels 21–23, see also Table 2), indicating a dominance of compound tool maintenance over manufacture. The summed probability radiocarbon curve reaches its lowest point in these levels, suggesting that this interval was dominated by small and brief occupations. As noted above, assemblages of the lowest and uppermost levels are also dominated by ephemeral camp debris. Retouch frequency, LVD, and the bladelet retouch index suggest that levels 24–28 may represent a period when occupations shifted between residential bases and short-term camps in roughly equal frequency.

Why so many expedient levels and so few curated ones? The late Pleistocene climatic sequences represented in (admittedly very distant) Greenland ice cores correspond only weakly to shifts in site use (Fig. 4). To explain our results we must look to the regional geographical context in which La Riera is situated and to general patterns of human response to climate change from the Early Pleniglacial to the Holocene in western Eurasia. The site is one of four that lie within a few dozen meters of each other in the valley of the Río Calabres, a small stream that disappears into a low limestone ridge (La Llera), only to re-emerge about a kilometer to the north at the Niembro estuary. Some 3 km to the south is the Peña Llabres, a steep escarpment some 715 m in elevation. Seven additional sites lie within about 2 km of La Riera (Fig. 7).

The 'short answer' to the question of why so many expedient levels probably can be found in the local topography and resource distributions in the vicinity of the site. As Margaret Conkey argued more than 30 years ago, La Riera can be considered an 'aggregation site', but it was probably the small cul-de-sac valley itself, rather than any particular site within it, that constituted the logistical base (Conkey, 1980). This view is supported by the exceptionally rich

Table 4
La Riera Climatic Data. Dates are estimated calibrated ranges based on age-depth model (see Fig. 4 and text).

Levels 29–30 (10.0–6.9 ka cal BP) – these reflect temperate, very humid climate like that of the past millennium (Butzer); high percentages of temperate AP (hazel, oak, elm, linden, walnut, alder, willow), ferns; approaching Holocene climax vegetation association (mixed deciduous forest); Lev. 29 is the Asturian *conchero* (dates refer to Lev. 29); Lev. 30 is the stalagmitic cap that seals in the La Riera sequence (not dated but must have formed under extremely wet, mild conditions likely similar to, but wetter overall, than those of Lev. 29).
Levels 27–28 (12.6–10.0 ka cal BP) – the end of Dryas III/Alleröd with resumption of cold, dry conditions as indicated by *éboulis* (Lev. 27) followed by warming, more humid conditions (Lev. 28), indicated by oak pollen, appearance of roe deer, boar; Lev. 27 is 'Azilian' or 'Azilian/Magdalenian'; Lev. 28 is 'Azilian' (characteristic flat harpoons). Most Azilian sites in Asturias are cold, dry (thus would equate with Lev. 27) but most of these sites are located inland at higher elevations. Lev. 28 is somewhat anomalous for its relatively temperate climate.
Levels 24–26 (13.6–12.6 ka cal BP) – Lev. 24 is cool to cold, humid with brief sharp cold snap, appearance of reindeer (Dryas III?) followed by the onset of reforestation after Dryas III. Levs. 25–26 have temperate, very humid climate that seems to mark the end of the Alleröd, beginning of Holocene. 'Upper Magdalenian' (i.e., harpoons)
Levels 21–26 (16–13.6 ka cal BP) – treated as a unit because of problems with chronology and environmental reconstruction (i.e., palynology, sedimentology don't agree with one another). Humid throughout but unstable with very humid cold conditions punctuated by colder, drier episodes (Dryas II- early Alleröd?); 'Upper Magdalenian' (i.e., harpoons).
(apparent hiatus)
Levels 17–20 (21–17 ka cal BP) – overall, this probably corresponds with Dryas I) – generally cold, dry conditions perhaps interrupted briefly by a short warmer interval (relative to bracketing levels – Bölling?) followed by a return to sharply colder, dry conditions (Dryas II); good agreement between sediments, pollen; end of full glacial conditions. Levs. 19–21 are 'Lower Magdalenian' (i.e., no harpoons) but statistically similar to underlying Solutrean levels.
Levels 12–16 (20.5–17 ka cal BP) – moist; more temperate than Levs. 2–11 but still cold throughout. Levs. 9–16 are Solutrean either because of diagnostic points or because they bracket levels with points; Lev. 18 is 'Lower Magdalenian' but statistically almost identical with earlier Solutrean levels.
Level 11 (22.8–20.5 ka cal BP) – Solutrean
Levels 4–10 (24.1–22.8 ka BP) – Pleniglacial Maximum; very cold and dry; almost no AP, even in protected locales; most severe conditions of the Upper Pleniglacial; Levs. 4–10 Solutrean.
Levels 1–3 (25.4–24.1 ka cal BP) – climate generally unstable, fluctuating but overall cold, moist (esp. in comparison to Levs. 4–8); regional climate highly unsettled, stormy during summer months and transitional seasons, subarctic cold during the winter. Lev. 1 (Aurignacian or Gravettian?) – somewhat warmer, very humid vs. Levs. 2–3 (Solutrean).

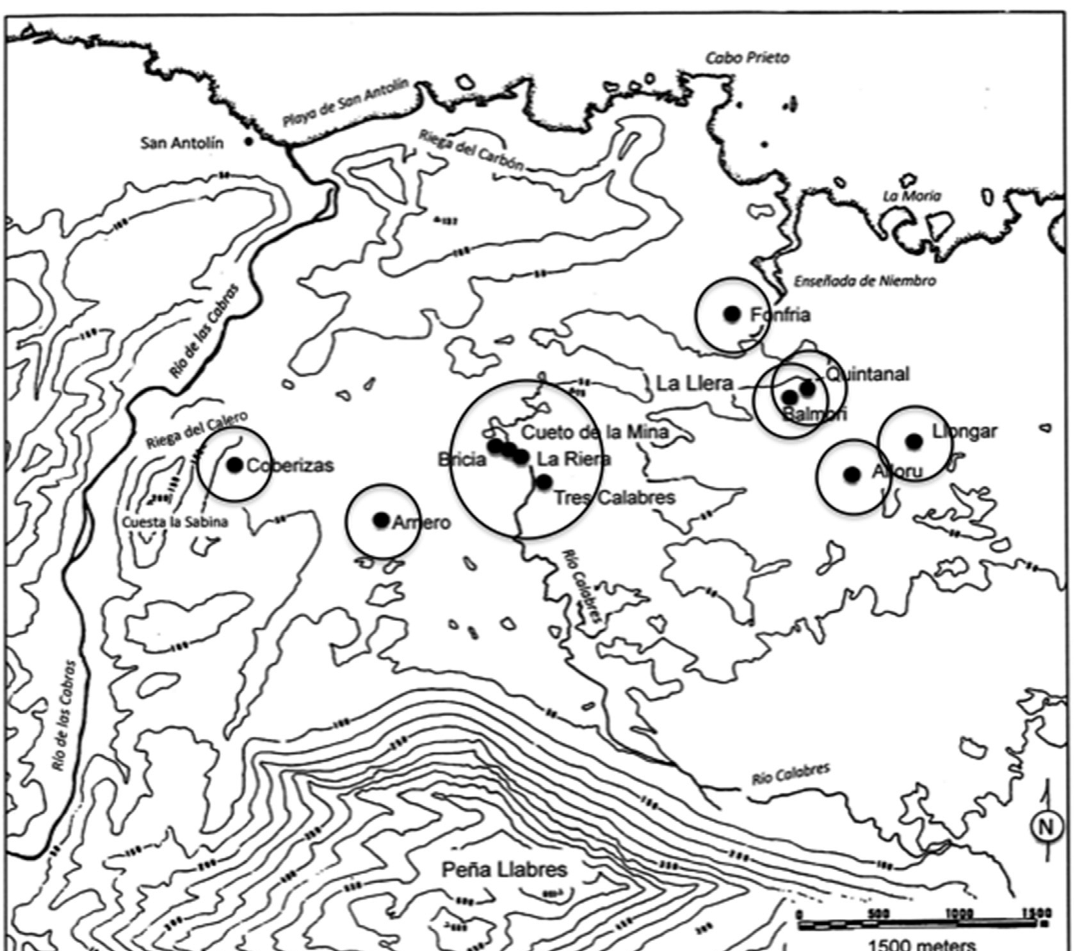

Fig. 7. La Riera – the local geographic context showing the locations of 10 neighboring sites. Note the proximity of the Peña Llabres escarpment (elev. 715 m) to the site (elev. 22 m) and the short distance from the site to the coastline.

resource mix found nearby, particularly those resources associated with the Niembro estuary. Shellfish (winkles, limpets), salmon, trout and *reo* (sea trout) were seasonally abundant there. Red and roe deer, boar and, in the rocky terrain of the Llabres ibex, abounded over much of the Upper Paleolithic and Mesolithic. The protected location of the valley appears to have mitigated the climatic effects of the Pleniglacial, Tardiglacial and early Holocene, a phenomenon noted by others in respect of the major river valleys that cross-cut the narrow coastal plain (e.g., Straus et al., 1981; Clark, 1983). The 'long answer' can probably be found in macroclimatic change during Marine Isotope Stage 2 (29–14 ka BP). As noted above, logistical mobility and expedient assemblages produced from base-camp occupations by far dominate the archaeological record of MIS 2 in western Eurasia (Barton et al., 2013, 2011). This is not particularly surprising given the arctic-like climate and patchy distribution of large game that characterized this region during the peak of the last glaciation. The La Riera sequence well fits this broader trend, even for its most curated assemblages.

9. Conclusions

It is important to note that these research conclusions are in broad agreement with those of the original investigators (Clark and Straus, 1986: 351–366, Clark et al., 1986: 325–350; Straus, 1986: 67–74, 219–236; Straus and Clark, 1986: 367–384). At least at La Riera and its environs they indicate (1) repeated aggregation of forager bands in the Río Calabres valley over long periods of time, possibly during the cold winter months when highland sites would have been difficult of access, and when dietary staples (esp. cervids, ibex) would have moved to lower elevations along the relatively warm coastal plain, (2) a dearth of curated assemblages in the site sequence and a dominance of expedient ones, possibly related to familiarity with the distributions of dietary staples, shellfish and tool stone locations, (3) the ability to support longer-term occupations by dispatching task groups from sheltered logistical bases in the topographically-constrained coastal plain where key resources are located in close proximity to one another, and (4) a rough correspondence between the (calibrated) dates and the phases of the last glacial that could explain why foragers in the Río Sella catchment aggregated in the coastal lowlands during the climatic extremes of the last glacial.

The WABI approach aims to maximize the behavioral potential of archaeological collections not always excavated to modern standards and the monographs that typically result from them. It does not depend on the illusion of pristine, undisturbed sites, nor type sites or sequences claimed to embody the full range of variation in the material remains of archaeological 'cultures,' nor techno-typological tool making traditions passed down from one generation to the next, nor are the index fossil tool types used to identify them accorded much importance. We maintain that practically all archaeological sites are depositional composites (palimpsests) accumulated over millennia by people whose existence lies beyond the resolution of our capacity to recover them. And even if we could recover them, what would they tell us? What generalizations about their behavior could be made from the activities of a few individuals in a moment frozen in time?

There is nothing new in the paleoecological framework that guides the WABI perspective (Barton et al., 2011). In fact, the title of the NSF proposal that made the La Riera excavation possible was 'Paleoecology at La Riera: Late Pleistocene Hunter-Gatherer Adaptations in Cantabrian Spain' (Clark and Straus, 1975). Its value lies in its capacity to make sense of the material remains of a past that cannot be captured by the conventional systematics. When placed in the landscape perspective adopted by behavioral ecology – and we acknowledge that we haven't done that here – the collection of methods subsumed under WABI, and its power and generality, has the potential to transform the archaeology of 'deep time.'

Acknowledgments

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