Economies Set in Stone? Magdalenian Lithic Technological Organization and Adaptation in Vasco-Cantabrian Spain

Lisa Marie Fontes

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ECONOMIES SET IN STONE?

Magdalenian Lithic Technological Organization and Adaptation in

Vasco-Cantabrian Spain

by

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A.B. Anthropological Archaeology, Hamilton College, 2009

M.A. Anthropology, University of New Mexico, 2011

DISSERTATION

Submitted in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

Anthropology

The University of New Mexico

Albuquerque, New Mexico

May 2016
DEDICATION

To Tom and Charlotte,
who helped me develop my interest in archaeology,
and who have remained supportive mentors since I left the Hill.

and to

Shannon,
I treasure our friendship.
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ECONOMIES SET IN STONE?
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Vasco-Cantabrian Spain

by

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A.B. Anthropological Archaeology, Hamilton College, 2009
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Ph.D. Anthropology, University of New Mexico, 2016

ABSTRACT
This hybrid dissertation explores how hunter-gatherer groups who lived during
the Initial and Lower Magdalenian archaeological periods (c.17-14,000 uncal. BP)
adapted their lithic technological organization to environmental complexity in the Vasco-
Cantabrian region of north coastal Spain. Four manuscripts that examine aspects of Last
Glacial hunter-gatherer adaptations are presented in this dissertation. The first three have
been published or are in press in the Journal of Anthropological Archaeology, Journal of
Archaeological Science, and Quaternary International. The last is a completed
manuscript that is under review by the Journal of Archaeological Method and Theory.
The first paper focuses on how archaeologists examine prehistoric transitions using a case
study from Urtiaga cave, Giupúzcoa. This case demonstrates that lithic maintenance was
a significant factor in Initial Magdalenian landscape-level adaptations. The second paper
summarizes the lithic and osseous industries (the latter studied by L. Straus), recovered
from the El Mirón cave and demonstrates the sites’ importance as a Lower Magdalenian
residential site in central Cantabria. The third manuscript explores hunter-gatherer lithic conveyance patterns based on four sites in central Cantabria (Altamira, El Juyo, El Rascaño, and El Mirón) and proposes that the Lower Magdalenian groups who occupied these sites shared an economic territory that expanded from Cantabria into western Navarra. Local raw material conveyance shows that shifting environmental zones was an important factor in how groups mover through the diverse Cantabrian landscape. The fourth manuscript investigates how Lower Magdalenian groups procured raw materials using a mathematical model that predicts toolstone production efficiency. Using samples from the same four central Cantabrian contexts, the paper explores the relationships among toolstone efficiency, lithic procurement, and Last Glacial mobility. Each case study presented as part of this dissertation contributes to archaeological understanding of how human groups adapted—particularly through technological management and movement—to the complex environments of north coastal Spain during the early Magdalenian period.
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Chapter 1: Introduction

Anthropologists have longstanding interest in how humans respond to environmental complexity and change. This kind of research has come to the forefront of the discipline, particularly as modern groups see the effects of global warming at their doorsteps. This project has focused on how hunter-gatherers who lived during the Magdalenian period (c. 17-11,000 uncal. BP; part of the Upper Paleolithic) in the complex, mountainous environment on the northern Spanish coast, adapted their lithic technologies to a world that was also gradually warming after the Last Glacial Maximum (LGM), and that, like the world people know today, was expanding in size (i.e., territory and population) and becoming ever more interconnected.

The Upper Paleolithic archaeological record (c. 40,000-10,000 uncal. BP) in Vasco-Cantabria is one of the richest in the world because humans occupied the region throughout the last Ice Age (Clark and Straus 1983; Freeman et al. 1988; Straus 1992, 2005, 2013), making it an ideal location to study long-term human-environmental interaction. Among the many succeeding archaeological cultures (sensu Breuil—also called “technocomplexes”) defined in this area, the Initial Magdalenian (IM; c. 17-16,000 uncal. BP) is characterized by only a handful of “transitional” assemblages identified throughout the region (see Chapter 2). In contrast, the Lower Cantabrian Magdalenian (LCM) (c. 16-14,000 uncal. BP) is known by its unique lithic and osseous technologies, artistic styles, subsistence regimes, and settlement patterns, described in detail later sections of this Introduction and in Chapters 3-5 (González Echegaray 1960; Straus 1992, 1996; Utrilla 1981, 2004).
This study focuses on Initial Magdalenian and LCM lithic technological adaptations by combining two economic frameworks: first, lithic technological organization, an Americanist approach that divides lithic economic behaviors into five inter-related components: procurement, transport, manufacture, maintenance, and discard (Nelson 1991); second, Human Behavioral Ecological (HBE) concepts grounded in Optimal Foraging Theory (OFT), which model cost/benefit relationships and argue that foragers will seek to increase benefits per unit of cost in scenarios related to prey choice, patch choice, mobility, and technological investment, among others (see for examples Bettinger 1987, 1991; Bettinger and Baumhoff 1982; Bird and O’Connell 2006; Fitzhugh 2001; Hawkes et al. 1982; MacArthur and Pianka 1966; Marín Arroyo 2009b; Surovell 2009; Torrence 1989; Winterhalder 1996). These frameworks were used to elucidate adaptive technological behaviors in each of the five lithic technological organizational categories. HBE and OFT were applied as interpretive frameworks in the case studies in Chapters 2 and 4; a mathematical model grounded in HBE/OFT was used in the Chapter 5 case study in lithic procurement to predict the influence of raw material production efficiency on LCM mobility.

These frameworks were coupled with a regional sampling strategy. While data from only five contexts are presented as case studies in this dissertation, a total of 19 contexts from 11 sites spanning the entire Magdalenian period were sampled as part of this project (totaling over 330,000 lithic artifacts; see Table 1.1). Landscape level sampling makes it possible to compare how the different environmental zones in Vasco-Cantabria influenced technological behaviors at each site.

The overall goal of this project was to understand how Magdalenian hunter-
gatherers adapted their technological strategies to variable environments and at what scales (i.e. landscape, site, toolkit) and organizational phases (i.e., procurement, manufacture, etc.) these adaptations were made. The case studies presented in Chapters 2-5 achieve this by assessing how Initial and Lower Magdalenian groups: procured and transported lithic toolstones, designed toolkit elements, maintained toolkits and toolstones, and patterned their lithic discard. Each case study is described in a brief abstract later in this chapter. This introduction contextualizes the case studies in Chapters 2-5 by presenting relevant background information about the Vasco-Cantabrian region, the Initial and Lower Magdalenian periods, and the samples/methods used as part of the project.

2. The Vasco-Cantabrian Region

2.1 Geography

The Cantabrian region of north coastal Spain is located in north-central Atlantic Iberia. The area includes the modern provinces of Asturias, Cantabria (formerly Santander), Vizcaya, and Guipúzcoa, the latter two are the westernmost provinces in the Basque country. The region is located at 43° north latitude, spanning 2° to 7° longitude from the Greenwich Meridian (Straus 1992). The area is geographically circumscribed: to the north by the Bay of Biscay, to the east by the Pyrenees, to the south by the Cantabrian Cordillera and Picos de Europa, and to the west by the Galician shield rock region (Straus and Clark 1983; Straus 1992). The narrow, coastal strip is mountainous, comprised of karstic limestone replete with caves, and cut by short, montane river valleys that limit littoral lowlands (Freeman et al. 1988; Straus 1992, 2005; Straus and Clark 1983). During the Late Last Glacial there would have been approximately 4-12 km of additional coastal
zone along the northern edge of the region due to sea level regression, although this addition would not have significantly offset the extraordinary amount of elevational change from the coast to the montane interior, a difference of >1000 meters. Together, these geographic features contributed to the substantial environmental patchiness and resource diversity found in this coastal zone (Freeman et al. 1988; Straus 1992, 2005; Straus and Clark 1983). These geographic and ecological factors, together with the long archaeological record in this region, make Vasco-Cantabria an ideal location to study human-technological-environmental adaptations during the Last Glacial period.

2.2 Paleoenvironment

The Magdalenian period in Vasco-Cantabria spanned several climate periods, including Lascaux (the end of the Last Glacial Maximum), Dryas 1 (Upper Pleniglacial), Dryas II/Bölling (Tardiglacial) and Dryas III/Alleröd (also Tardiglacial), before the Holocene, which is associated with the Azilian/Mesolithic, began (Hoyos 1995; Straus 1992). At the end of the Last Glacial Maximum (c.20-17,000 uncal. BP), when Solutrean groups occupied the landscape, western Europe was characterized by extreme cold and aridity (although it was more humid in Vasco-Cantabria than it was in many regions of France) (Hoyos 1995; Straus 1992, 2005). Dryas I (c. 17-14,000 uncal. BP and coinciding with the Lower Magdalenian) brought gradual climatic amelioration to the region and increased humidity (Cuenca-Bescós et al. 2009), however, northern Spain was still a largely treeless, grass- and heath-land with the remnants of montane glaciers in high peaks (Pokines 1998, 2001; Straus 1992). During Bölling and Dryas II (c. 14-12,400 uncal BP) the region saw the development of more moderate, temperate environmental conditions to the region that gave way to the Middle Magdalenian cultural expansion.
Finally, Alleröd (12,400-11,000 uncal. BP)—interrupted the brief cold event of Dryas III (11,000-10,200 uncal. BP)—continued the warming trend at the onset of the Holocene. The beginning of Azilian “Epi-Magdalenian” cultures came during Alleröd (Straus 1992).

2.3 Lithology of Northern Spain

There is significant geological variation in the Vasco-Cantabrian region. The bedrock in western Asturias, the westernmost province in the region, is comprised of Paleozoic quartzites and slates, while the bedrock in the eastern half of the province is a complex mix of rocks, some with Carboniferous and Cretaceous flints sensu lato. Cantabria, a central province, is primarily Cretaceous limestones. The easternmost provinces of Vizcaya and Guipúzcoa are also composed of Cretaceous limestones, however, these include higher quality flints than those in Cantabria and Asturias (Tarriño 2000; Sarabia 1991, 2002; Straus 1992, 1996, 2002; Rissetto 2004, 2009). The best (in terms of knapping characteristics) and most widespread flints are located in Vizcaya and Guipúzcoa, decreasing westwardly toward Asturias (Straus 1996). Lithic assemblages from each province reflect this trend: sites in Asturias include appreciable amounts of quartzites and ophites (Straus 1996), while Guipúzcoan assemblages are almost exclusively flint. People would at times travel long distances to get flints, for example, occupants in El Mirón, a montane site in interior Cantabria, would have routinely traveled 50-70 km to procure flints from the Barrika outcrop in Vizcaya (Rissetto 2004, 2009; see also Chapters 2, 4 and 5). Magdalenian groups also found local stones in riverbeds and other outcrops, particularly limestones and mudstones (Straus 1992). While archaeologists have assumed that the best flints are located in Guipúzcoa and Vizcaya, it is possible that Magdalenian hunter-gatherers exploited coastal sources that are now
submerged. Thus, archaeological interpretations of how local lithology influenced lithic assemblage composition are based solely on the current understanding of the available raw materials, and many flints used by Magdalenian settlers have yet to be identified (Rissetto 2004; Straus 1996; see Chapters 4 and 5). Recent work by Tarriño et al. (2014) has summarized many of the known outcrops in the Vasco-Cantabrian region, including major flint resources like Treviño and Urbasa, both located south of the Cantabrian Cordillera but which regularly occur in lithic assemblages from sites along the coast. Regional lithology and specific raw materials are described in more detail in Chapters 2, 4, and 5. A major summary of the lithic raw materials used by Vasco-Cantabrian Magdalenian groups was made as a part of this project in order to understand lithic raw material conveyance and inter-site economic relationships (see Chapters 4 and 5). These materials were characterized visually in ad hoc reference collections made for each site, which were later directly compared to each other and to two archaeopetrographic reference collections. Chapters 2, 4, and 5 describe this process in more detail and Appendix C includes descriptions and photographs of all of the raw materials identified as part of this project.

3. Late Last Glacial Archaeological Cultures

This research primarily focuses on the Lower Magdalenian period; the Initial Magdalenian is only the subject of Chapter 2. This section briefly describes the three cultural periods discussed in detail in the case studies in Chapters 2-5: Solutrean, Initial Magdalenian, and Lower Magdalenian.

3.1 Solutrean

The Solutrean cultural period (c. 20-18,000 uncal. BP) was characterized by an
extremely cold and arid landscape related to the Last Glacial Maximum (LGM) (Straus 2000; Straus et al. 2002). The LGM forced people to leave their northerly hunting territories—they gradually contracted their settlement area in western Europe to glacial refugia like Vasco-Cantabrian Spain and southwest France, a phenomena represented archaeologically in Vasco-Cantabria by an increase in site numbers relative to the preceding periods (Straus 2000). As territories contracted, Solutrean hunter-gatherers likely packed themselves into the slightly more humid, and therefore favorable, Vasco-Cantabrian region (Straus 2000). Solutrean assemblages in Vasco-Cantabria, known from important sites like La Riera, Las Caldas, and El Mirón (Corchón 1999; Straus 2000; Straus and Clark 1986), are principally defined based on reliable, lethal shock weapon tips, typically with shouldered or concave bases (unlike the large willow leaf and foliate points found in France). These diagnostic projectile points would have required great skill to manufacture, including mastery of pressure flaking techniques. While reliable in hunting, these weapon tips were notoriously breakable and costly to manufacture and replace (Straus 2000). These were replaced in “popularity” by more maintainable antler point and microlith insert composite hunting technology in the Magdalenian. Straus (2000) argues that reliability would have trumped maintainability (sensu Bleed 1986) in the uncertain LGM environment, where resources were patchier, highly mobile, and seasonally scarce. Large weapon tips would have done considerable damage to animals (shouldered points in particular would have been difficult to “shake loose” once the animal was shot), effectively bleeding and killing them and making them easier to track and pursue.

While projectile technology is the major defining characteristic of the Solutrean
period, these hunter-gatherers made other significant inventions, including the eyed bone needle, which would have allowed them to sew clothes to combat the extreme Last Glacial cold (Stettler 2000; Straus 2000). Solutreans are also known for having large territories separated by little used areas; these areas have been identified based on flint conveyance and stylistic variability among projectile points (Banks et al. 2009). While this separation allowed regional technological styles to develop, people did not lose contact between vast territories; connections likely occurred to facilitate trade, intermarriage, ideas exchange, rituals, etc. (Straus 2000). Technological similarities among projectile industries further indicate that Solutrean peoples maintained connections. Inter-group communication was likely a form of economic or social security, allowing groups to increase and maintain their knowledge about the environment (Straus 2000; Whallon 2006). Solutrean-age faunal remains from Vasco-Cantabria also show evidence of situational, specialized red deer and ibex hunting in addition to use of fish and shellfish, which contributed to broad diets (Straus 2000; Straus and Clark 1986). These adaptations—technological, territorial, and subsistence-related—likely constitute human responses to an extreme, mid-latitude glacial environment. The relationship between the Solutrean and the development of the Initial Magdalenian is discussed in greater detail in Chapter 2.

3.2 Initial Magdalenian

The transition from Solutrean to Lower Magdalenian has been the subject of considerable debate for the past four decades (Aura 2012; Corchón 2005; Gonzalez Echagaray 1960; Stettler 2000; Straus 1992, 2013; Straus and Gonzalez Morales 2010; Straus et al. 2008; Utrilla 1981). This debate has its roots in how archaeologists have
historically approached Upper Paleolithic chronology. Many early discoveries from northern Spain were compared to French Magdalenian stage systems (particularly those defined by Breuil, in which Magdalenian is broken into eight stages from Magdalenian 0 to 6b) (Aura 2012; Straus 1992; Gonzalez Echegaray 1960; Utrilla 1981). These comparisons were problematic because the hunter-gatherers who lived in these different environments had different cultural histories (see for example Banks et al. 2009, 2011). There are two major hypotheses for how the Magdalenian developed: (1) that the Initial Magdalenian industries in Vasco-Cantabrian Spain developed based on inter-group contact between Spanish groups and those people manufacturing so-called Badegoulian industries in southwest France (Aura 2012; Bosselin and Djindjian 1999); and (2) that the Initial Magdalenian (and succeeding Lower Magdalenian) developed in situ from the preceding Solutrean (Cazals and Bracco 2007; Stettler 2000; Straus 2005, 2013; Straus et al. 2008). While this issue remains unresolved, compelling arguments have been made for in situ development of the Cantabrian Magdalenian (see Chapter 2 for further evidence therein). Some Archaic or Initial Magdalenian sites were not occupied during the Solutrean (but not El Mirón, and maybe not El Rascaño or Urtiaga either), indicating that with the Initial Magdalenian came a change in settlement. It is plausible that Solutrean territories contracted and new, smaller, Magdalenian territories were established and based in river valleys (Straus 1986; Utrilla 1981). Additionally, large, lethal foliate points were progressively replaced by backed bladelets and resilient antler point systems (Straus 2013). “Archaic” components of lithic assemblages (large flakes and flake tools including sidescrapers, denticulates, and notches made on non-flint, often local, raw materials) appear in appreciable amounts, though this may have been
functionally related to on-site activities, as “archaic” assemblages are common in the Cantabrian region throughout the Upper Paleolithic (Straus et al. 2014). Stettler (2000) also illustrates gradual change from Solutrean to Magdalenian using organic artifact classes: needles became smaller and more finely crafted and perforated red deer teeth became more common (perhaps in relation to subsistence intensification and “wild harvesting” [see Freeman 1973]). While scholars debate Initial Magdalenian origins, it is clear that its appearance provided a base from which the Lower Magdalenian developed.

3.3 Lower Cantabrian Magdalenian

3.3.1 Research History

Early researchers who worked in Vasco-Cantabria defined the Lower Magdalenian as the Magdalenian III, correlating it to the French stage systems defined by Breuil (1912) and later Bordes (1958) (Clark and Straus 1983; Ducasse 2012; González Echegaray 1960; Straus 1992). This correlation was based on excavations at El Juyo (by P. Janssens and J. González Echegaray) and La Lloseta (by F. Jordá) in the late 1950s, whose assemblages were compared to the French Magdalenian III sites of Laugerie-Haute and Le Placard (Clark and Straus 1983). These generalized comparisons were based on vague resemblances among tool industries (González Echegaray 1960). Similarities between radiocarbon dates furthered the Magdalenian III comparison, with dates of 15,500+/- 700 at Altamira (Freeman and González Echegaray 2001) and 15,300 +/- 700 at El Juyo falling within the Magdalenian III time range (Barandiarán et al. 1985; Clark and Straus 1983). Later, researchers like Clark and Straus (1983) argued that more behavioral information could be discerned from the Spanish archaeological record by ignoring the French phase schema and not using them as a base for analysis. Researchers
have now abandoned use and correlations to the early phase systems (French researchers included), and have proposed new definitions of the Lower Cantabrian Magdalenian as a distinctive regional culture with its own diagnostic artifacts (González Morales and Straus 2009; Straus 1992). The Magdalenian period in Vasco-Cantabria is now divided into two principal technological phases: Lower and Upper, respectively before and after the invention of the barbed antler harpoon c. 13,000 uncal. BP (Straus 1992, 2005, 2013). However, additional “transitional” periods are now also the subject of regular research, making the Magdalenian chronology one with four phases defined based on various changes in settlement, technology, art, and subsistence practices: Initial (c.17-16,000 uncal. BP), Lower (16-14,400 uncal. BP), Middle (14,400-13,000 uncal. BP) and Upper (13-11,500 uncal. BP) (Straus 2005, 2013).

3.3.2 Important Sites and Lithic Assemblage Variability

Archaeological contexts are classified as LCM based on high percentages of so-called nucleiform endscrapers or backed bladelets; the presence of quadrangular section antler sagaies with “tectiform” decorations; or red deer scapulae engraved with images of hinds or other ungulates (Straus et al. 2008). While many LCM sites have been identified in the region, some played a greater role than others in terms of defining archaeological interpretations of LCM settlement, subsistence, and chronology. This section aims to summarize these sites. Early research in LCM systematics was based largely on excavations at El Juyo (Cantabria), a large, coastal zone site with a multi-seasonal occupation and structures related to a “sanctuary” (Barandiarán et al. 1985) and El Rascaño, a small montane site with short and focused occupations principally related to ibex exploitation (González Echegaray and Barandiarán 1981; Straus 1992; Utrilla 1981).
Based on these sites, which are approximately 30 km from each other, archaeologists have hypothesized that LCM groups settled in coastal residential sites where they exploited littoral resources (fish, shellfish, red deer) and made logistical trips to montane sites to exploit ibex. Coastal sites were also distinguished for their focus in “wild harvesting” of red deer, especially hinds and their young (Freeman 1973). Coastal residential sites also became known as the focus of artistic, and possibly ritual, activities. This interpretation is based on sites like Altamira, which was perhaps a major aggregation site as well as a place known for its art and fall-spring occupations focused on red deer, fish, and shellfish exploitation (Conkey 1991; Freeman et al. 1988; Freeman and Gonzalez Echegaray 2001; Straus 1976/77).

Among LCM sites there is significant lithic assemblage variability, defined based on variations in the relative percentages of diagnostic lithic tools in a sample (i.e., nucleiform endscraper, backed bladelets, etc.). This variability has its roots in scholars trying to apply French lithic typologies to Spanish collections (Utrilla 1981), a process complicated by differing regional lithology. Spanish lithic raw materials are generally much smaller in size than those available in France, which influenced what could be produced from a nodule. LCM assemblage variation primarily concerns two artifact types: nucleiform endscrapers and backed bladelets. Nucleiform endscrapers/bladelet cores comprise 50+% of tool assemblages in the western provinces (based on the El Juyo “facies”) and a much smaller percentage, 13.5 %, in the Basque country (Utrilla 1981, 2004). Archaeologists have long debated whether nucleiform endscrapers were endscrapers on cores or unused, exhausted cores (Straus 1992). A microwear analysis of nucleiform endscrapers by Domingo et al. (2012) defined these pieces based on
regularized core edges and found that as much as 80% or as little as 9% of a sample have been used (based on LCM levels at El Rascaño, a site known for its nucleiform endscrapers), that is to say, whether or not these cores had a secondary use as scrapers is highly variable. Regardless of use, the fact that these scrapers appear in very large quantities in some occupations suggests something special about those occupations (Straus 1992). It is also possible that the presence of nucleiform endscrapers is correlated to lithology, as Basque sites with access to better flints have fewer of them. Second, backed bladelets were a microlithic technology that was used in conjunction with antler sagaies as hunting weapons (Keeley 1988; Straus 1992; Utrilla 1981). These artifacts are susceptible to being missed by excavators, particularly if fine-mesh water screening techniques are not employed in excavation (Freeman et al. 1998; Straus and Gonzalez Morales 2008). This distinction has been confirmed even in excavations using rigorous screening processes, indicating that a difference in the relative abundance of backed bladelets was likely real and functionally significant (Straus 1992). An additional significant note about LCM lithic variability lies in reduction sequences, or chaînes opératoires, between Basque sites and those in Cantabria and Asturias. Basque knappers favored lamellar reduction on high-quality flints. In contrast, as one samples sites progressively westward toward Asturias (Utrilla 1981, 1989), knappers manufactured more flakes on quartzites (with flints being reserved for tools). Lithology and differences in locally available raw materials likely influenced these trends.

Several sites can illustrate variability in LCM lithic tool assemblages. For example, the lithic tool assemblages from El Juyo cave have notable differences. In El Juyo Levels 4, 6, and 8, endscrapers range from 27% to 11% of the tool assemblage, and
seem to be inversely correlated with backed bladelets, which comprise between 12% and 39% of those same levels (Barandiarán et al. 1985; Straus et al. 2008). To contrast, at El Rascaño cave Levels 3 and 4/4b, the tool assemblages contained 34-37% nucleiform endscrapers and hardly any backed bladelets—0-5% (González Echegaray and Freeman 1981; Straus et al. 2008). At another coastal site, La Riera cave, which is located on an eastern Asturian coastal plain, 62-74% of its LCM lithic tool assemblages (Levels 18-20) are comprised of backed bladelets, while only 4-6% of the tools are nucleiform endscrapers (Straus and Clark 1986). El Mirón cave, a montane site in the Ruesga valley where LCM groups exploited both ibex and red deer, only further muddles how archaeologists might define a “typical” LCM site (Straus et al. 2008). The LCM lithic tool assemblages from El Mirón cave are dominated by backed bladelets and nucleiform endscrapers that were made using high quality, non-local flints from coastal Vizcaya and from outcrops south of the Cantabrian Cordillera (Rissetto 2009; Straus and González Morales 2012; see also Chapters 4 and 5). When compared to assemblages from La Riera, El Juyo, and El Rascaño, the picture is clear: there is no typical LCM tool assemblage (Straus et al. 2008).

It is difficult to explain why LCM tool assemblages are so variable. Some lithic tool assemblage variability could relate to lithology—this is likely why Basque sites like Ekain and Eralla show emphases in lamellar lithic production: high quality raw materials were directly available (Altuna 1984; Utrilla 1981). It is possible that some of the internal variability is site-situational, that lithic assemblages somehow relate to activities carried out at each site (i.e., animals pursued, position in settlement system, occupation duration, etc.). Some lithic variability may also relate to sample sizes; for example, the excavation
at El Rascaño was spatially limited, partly due to the cave size (González Echegaray and Barandiarán 1981). Other excavations were not modern (e.g., Altamira and El Castillo), where researchers used excavation techniques and collections standards that were less precise than those archaeologists use today; and/or modern excavations carried out were limited in scope (again, e.g., Altamira) (Freeman 1988; Freeman and González Echegaray 2001). Another important point to consider is the classification system itself: that archaeologists have made comparisons based solely on lithic tools has limited their interpretations to a relatively small portion of the materials LCM groups actually produced. That is to say, the lithic debitage analyzed as part of this study provide a greater context to how variation in lithic tools related to hunter-gatherer settlement systems and toolkit management strategies (Chapters 2, 4, and 5). These issues have also been raised in other world regions and time periods and present a major challenge for archaeologists—that they not only need to determine how to document behavioral variability, but need to explain its significance (see Adler and Jöris [eds.] 2008 and Shea 2011).

3.3.3 Lower Magdalenian Site Distribution

The Lower Magdalenian is defined at 52 sites in the Vasco-Cantabrian region 27 of which were first occupied during this period, a slight increase from the number of sites known dating to the preceding Solutrean period (Straus et al. 2000). Archaeologists believe that this change may relate to larger human populations inhabiting the region (Straus 1992). Magdalenian sites were likely chosen based on their favorable characteristics (i.e., exposure, shelter, strategic view) and proximity to resources (i.e., water, toolstone, comestibles). For example, sites like El Rascaño, Collubil, and
Bolinkoba were hunting stands that were probably selected for their proximity to ibex (González Echegaray and Barandiarán 1981; Marín Arroyo 2009; Straus 1992; Utrilla 1981). Magdalenian sites form distinct clusters throughout the Vasco-Cantabrian region: in the Nalón valley of central Asturias; along the Sella River; in coastal Asturias near the Bedón river (Posada de Llanes); on the wide coastal plain today occupied in part by the Holocene Bay of Santander and adjacent interior valleys (Río Pas and the Miera valley); along the Río Asón; near the Holocene Guernica estuary; and near the coast between the Urola and Deva rivers (Straus 1992; Utrilla 1981). These clusters may have been basic localized LCM settlement/territorial zones (Utrilla 1981). These small territories were confirmed based on Rissetto’s (2004) study of lithic raw material conveyance in the Río Asón drainage, which indicated north to south local procurement during the Lower Magdalenian, evidence consistent with an interpretation of groups moving up and down river valleys (however, see Chapter 4 for a different interpretation). There are different types of sites in each drainage—artistic “sanctuaries”, lithic reduction sites, residential bases, hunting locations for red deer or ibex slaughter, etc. (Freeman 1973; Straus 1992; Utrilla 1981).

LCM archaeological residues reflect dense human occupations. Many LCM deposits are thick stratigraphic horizons without sterile layers. Altamira and El Castillo caves are famous for their significant LCM occupations (El Castillo’s LCM layer was two meters thick!); Santimamiñe, El Mirón, El Cierro, El Juyo, and Cualventi also contain exceptional LCM palimpsest horizons. These thick deposits compress (presumably) reiterated occupations into single units that can be difficult for archaeologists to parse (Bailey 2007; Ontañón 2003). Unlike Magdalenian open air sites
in France (e.g. Verberie, Pincevent, Marsagny, and Etiolles in the Paris Basin), western Switzerland (e.g. Champreveyres and Monruz), and the German Rhineland (e.g. Gönnersdorf and Andernach), where archaeologists have learned extensively about hunter-gatherer spatial organization, resource sharing, and social relationships, cave sites offer archaeologists a diachronic perspective that often eliminates sophisticated spatial analyses, barring exceptional preservation (see Audouze and Enloe 1997; David 1992; Debout et al. 2012; Enloe and Audouze 2010; Janny 2010; Keeler 2010; Leesch 2012; Pigeot 2010; Sano 2012; Street et al. 2012; Symens 1986; Weniger 1987; Zubrow 2010; and Zubrow 2010a, 2010b). Archaeologists can place cave sites within larger settlement systems (see for example Utrilla 1981), however, archaeologists cannot assume that cave sites filled the same niche within a settlement system for the entirety of a cultural period. This is not only an issue for the Magdalenian, but for other Upper Paleolithic periods and regions; archaeologists must balance site types, functions, and formation processes when they make their interpretations (Bailey 2007).

Finally, Lower Magdalenian sites located in the modern Cantabria and eastern Asturias provinces indicate a distinct sub-regional culture. This Lower Cantabrian Magdalenian, which may represent hunter-gatherers with a distinct ethnicity or membership in a socially defined band, is defined on the basis of its art, particularly the presence of red deer hinds both on portable engraved scapulae (found at Altamira, El Castillo, El Rascaño, and El Mirón, among others), and in cave art. These portable engraved items were not practical objects, and likely had social or ideological roles for their makers (González Morales and Straus 2009; Straus 1992). Cave and/or portable art in this region is some of the most prolific in the world for the Magdalenian, including
some true “super sites”: La Paloma, Tito Bustillo, Las Caldas, Cueto de la Mina, Altamira, El Pendo, El Castillo, El Valle, and Urtiaga. Among these, Altamira, Tito Bustillo, and El Castillo are some of the most rich and complex art sites in the region (Bicho et al. 2007; Straus 1992). Red deer are the most represented of any animals in Lower Cantabrian Magdalenian cave art; they were drawn in quantity at Altamira, El Castillo, and El Cierro (Utrilla 1981). Bovines are also significantly represented in LCM cave art, especially at Hornos de la Peña, Altamira, and Rascaño (possibly an engraving) (Utrilla 1981). Other representations include horses, ibex, fish, serpents, and geometric symbols--lines, shapes, and dots of unknown meaning (Utrilla 1981). It is possible that these shared symbols present in caves throughout Cantabria and Asturias represent a regional communication network or regional band, perhaps the same group with the portable red deer motif items. These motifs have only been discovered at sites in Cantabria and Asturias—not in the Basque portion of Vasco-Cantabria (Straus 2013). It is possible that there was a cultural difference among the hunter-gatherer bands occupying these areas. It is also worth noting that some LCM sites in Cantabria are major art loci, while others have little to no rock art (or evidence of portable art, for that matter) (Straus 1992). Why art is differentially represented throughout the region is a mystery, but discoveries in the Basque sector are beginning to close the abundance gap vis-à-vis Cantabria and eastern Asturias. It could be the result of archaeological sampling or may have been a real functional, cultural, or social difference among the activities that occurred at Lower Magdalenian sites.

3.3.4 Lower Magdalenian Subsistence Adaptations

Fauna recovered from archaeological deposits can provide archaeologists with a
wealth of information about local environments, including species’ adaptability, presence of microclimates, and how humans selected comestible species (and meat cuts) (Altuna 1972; Freeman 1973; Marín Arroyo 2009; Pokines 2000; Straus 1987). LCM settlers chose among many animal species in their subsistence obtaining forays. Three kinds of sites have been identified as different types of hunting grounds, these include:

(1) sites situated in relatively open coastal areas yet close to rocky terrain, where groups pursued red deer in addition to ibex and other species, e.g., El Castillo, La Fragua, Santimamiñe, Lumentxa, Urtiaga, Ekain, Aitzbitarte IV, La Riera, etc.;

(2) sites that are situated relatively far from mountain areas where people slaughtered red deer en masse, e.g., El Pendo, Cueva Morín, Atxeta, Altamira, El Juyo, etc.; and

(3) sites located in the Cantabrian interior in areas with steep hillsides—where hunting sites were used to pursue montane species like ibex, e.g., El Rascaño, Piélago, Bolinkoba, Silibranka, Lezetxiki, Ermittia, Amalda, Erralla, etc. (Altuna 1972; Freeman 1973; Marín Arroyo 2009). (El Mirón reflects an exception to these three categories, being a montane residential site with significant ibex and red deer exploitation.) LCM groups likely invested their time to logistically organize mass kills of important game species. Freeman (1973) called this behavior “wild harvesting”: where LCM groups slaughtered multiple red deer in mass kills, especially hind and fawn herds (stags live separately from hinds the majority of the year). This strategy appears widespread in the Vasco-Cantabrian region, with evidence of it at El Juyo, Ekain, Cueto de la Mina, La Riera, and El Mirón (Freeman 1973; Straus 1992, 2005; Straus and González Morales 2012), and extended beyond red deer to other dominant game species, especially ibex,
which were hunted from bases specifically located to track and capture the game (Straus 1987, 2005; Utrilla 1981). It is likely that Magdalenian groups used natural landforms to aid in harvesting game. Sites are often located in topographic areas that could have been used to naturally drive animals into narrow gorges, river crossings, cul-de-sacs, etc. Ibex hunting likely involved driving goats upslope toward hunters (Straus 1987, 1992). Groups likely watched herds and planned ahead to achieve hunting success (Straus 1992).

Magdalenian foragers also systematically exploited large numbers of limpets and periwinkles at sites along the eastern Asturias and Cantabrian coastline (e.g., Altamira, El Juyo) (Freeman 1973; Straus 2005). Fish, especially salmon and trout remains, are abundant at many sites near the coast along interior rivers, even in Magdalenian levels with and without harpoons (Straus 1992, 2005). Overall, LCM subsistence fits into the overall Upper Paleolithic regional trend of groups circumstantially specializing their hunts around game species they could kill in large quantities, while intensifying their overall subsistence by pursuing species like fish, shellfish, boar, roe deer, etc. (Straus 1992, 2005). This strategy was likely directly correlated to the unique geographic circumstances found in the Vasco-Cantabrian region: groups could exploit a wide variety of resources in relatively small territories because of ecological variability in this patch, high relief, coastal region.

3.4 Summary of Magdalenian Occupations in Vasco-Cantabria

The Vasco-Cantabrian Magdalenian archaeological record shows three general trends:

(1) site location and distribution (with exception of some seasonal residential shifts into the montane interior consistent with climatic amelioration) (Marín Arroyo
2008, 2009; Straus and Gonzalez Morales 2012; Utrilla 1981);

(2) raw material exploitation, (with exception of shifts in use of non-local flint consistent with changes in site catchment areas (see Marín Arroyo 2008; Rissetto 2004, 2009); and

(3) subsistence (with a continuing trend in overall species diversification combined with situational specialization in red deer and ibex hunting) (Straus 1992; Straus and Gonzalez Morales 2012).

Lower Magdalenian settlements are defined on the basis of small territories and distinctive material culture, namely nucleiform endscrapers, “tectiform” decorated quadrangular-section osseous points, and engraved red deer scapulae (Barandiarán 1989; Straus 2013; Rissetto 2004; Utrilla 1981). Subsistence systems were collector-based, with groups sometimes moving from coastal residential sites to specialized hunting stands for “wild harvesting” of resources, part of a stable subsistence strategy aimed at obtaining the diverse terrestrial and aquatic species present in the Cantabrian ecotones (Binford 1980; Freeman 1973; Straus 1986, 1992; Rissetto 2004; Utrilla 1981). While LCM groups were a well-defined regional band based on distinctive art styles, they likely had limited extra-local contact with French groups (as evidenced by an atlatl hook found at El Mirón, nearly identical to those of the same age found at Roc de Marcamps [Gironde] and Le Placard [Charente]; see Gonzalez Morales and Straus [2009]). Contacts between these groups likely encompassed a variety of activities--intermarriages, rituals, exchange of ideas/beliefs, technological information sharing, etc. (Conkey 1980, 1991; Straus 1992; Whallon 2006; Whallon 2011; Whallon and Lovis 2011). Groups also may have served as insurance for each other in times of resource crisis (Fitzhugh et al. 2011; Spielmann
Additionally, it is possible that groups maintained networks to acquire information outside of their own small territories (Lovis and Donahue 2011; Utrilla 1981; Whallon 2006). There are several important features of the Magdalenian period as a whole (i.e., throughout western Europe), there are several important features: (1) group movements as part of the northward re-expansion of the human range following the LGM; (2) development of distinctive cultural regions (at least 16, including Vasco-Cantabria); (3) long distance contacts; and (4) regional ecologies and related adaptations (Otte 1992, 2012). The Magdalenian as a whole can largely be understood as an issue of synchrony—simultaneous development and contact among regional groups (Cazals and Bon 2007). Recent archaeological work has focused on better defining these regions, understanding unique human adaptations in each, and assessing to what extent groups maintained contacts between each area (Banks et al. 2009, 2011; Cazals and Bon 2007; Cazals and Bracco 2007; Clark 1994; Gamble 1983; Otte 1992, 2012; Rensink 1995, 2000; Schwendler 2012; Straus 1992, 2013; Straus et al. 2012; Wobst 1976). Each Magdalenian region presents its own unity and diversity—variation that is a matter of time, space, and regional style—the result of polygenism, diachrony, displacements, dispersion, adaptation, and taphonomy (Otte 1992). Archaeologists must dissect what factors influenced these adaptations to fully define/understand Magdalenian regional variants, which were unique in the span of human history.

4. Frameworks and Methods

4.1 Lithic Technological Organization

Ethnographic studies of hunter-gatherers indicate that these groups’ spatial
organization is strongly tied to the spatial structure of key resources within the landscapes they inhabited, some that were fixed and others that seasonally varied (Binford 1978, 1980; Gould 1980; Kelly 2007; Rensink 2000). Hunter-gatherer mobility is spatially continuous, characterized by seasonal residential and/or logistical moves related to these resources. Mobility and subsistence activities that occurred in the past directly impacted the structure of the prehistoric material remains found today (Binford 1979, 1980; Rensink 2000). Archaeologists must study landscapes (i.e., geographic regions) in addition to individual sites in order to understand patterns and variability in past human behavior. By investigating landscape-level behavioral variation in the archaeological record, it is possible to understand issues of hunter-gatherer flexibility and its resulting influence on the material record (Binford 1980; Price and Peterkin 2000; Rensink 2000). This project assessed Magdalenian hunter-gatherer adaptations from a lithic technological perspective. Lithic technology is ideally suited to understanding human behavioral variability at the landscape level because it is reductive. Every activity that required stone tool modification (i.e., raw material preparation, manufacture, use), has an archaeological trace that differed in character based on at what point the activity occurred within a reduction sequence (Andrefsky 2004, 2009; Shott 1986, 2004). Archaeologists can use the lithic technological organization framework, a study of “the selection and integration of strategies for making, using, transporting, and discarding tools and the materials needed for their manufacture and maintenance” (Nelson 1991:57) to understand adaptive variation in prehistoric lithic economies. Archaeologists working within this framework seek to learn how prehistoric people designed their toolkits in behavioral context, as opposed to the archaeological context in which the lithics were recovered (see Schiffer
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Archaeologists reconstruct systemic contexts using lithic artifacts by isolating the different transformations that the stones underwent as materials were selected, transported, manufactured, used/maintained, and discarded. Incorporating analyses that address all of these factors allows archaeologists to reconstruct past technological behavioral systems in detail and better understand how people adapted to various environmental, economic, and cultural factors. While technological organization was likely impacted by an interplay of all of the factors listed above, researchers can only pinpoint some of these components in the archaeological record. If lithic technology is interpreted as primarily functional in purpose (i.e., Binford 1979; Torrence 1989), those factors that influenced technological organization were likely confined to environmental and economic realms. Three factors have been considered particularly influential and/or constraining on lithic assemblages: raw material availability (Andrefsky 1994; Straus 1996), resource use (Binford and Binford 1969), and mobility/organization (Binford 1980; Jones et al. 2003; Kelly 2007; Nelson 1991; Torrence 1989). This project investigates lithic technological organization using a sample of sites with differing raw material availability, resource use, and occupational histories, making it possible to assess how the variable Vasco-Cantabrian landscape contributed to Magdalenian human adaptations.

4.2 Human Behavioral Ecological Modeling

Human Behavioral Ecology (HBE) is a general theory in anthropology that is derived from Evolutionary Ecology. It is focused on the evolution of adaptive behavior (Foley 1985; Winterhalder and Smith 2000). HBE archaeological research is often focused on optimal foraging theory (OFT), a principle asserting that humans will strive to
be optimal by seeking the greatest return for the least effort, consequently improving their reproductive fitness (Foley 1985; Smith 1983; Winterhalder and Smith 2000). Optimality is often a main aspect of models related to prehistoric food choices (e.g. prey choice model, patch choice model, etc.) (see for example Bettinger et al. 1997; Bird and Bliege Bird 1997; Boone 2002; Foley 1985; Hames 1989, 1992; Hames and Vickers 1982; Hawkes et al. 1982; Kelly 2007; Metcalfe and Barlow 1992; Schoener 1971; Smith 1979, 1983, 1987; Smith and Winterhalder 1992; Vayda and McCay 1975; Winterhalder 1983; Winterhalder and Smith 2000). In subsistence models, foragers who have the most efficient feeding behaviors have the greatest reproductive fitness (Foley 1985; Hames and Vickers 1982; Kelly 2007; Schoener 1971; Winterhalder and Smith 2000). Optimal behaviors are not static: they are predicted to covary with environmental variance (Hames and Vickers 1982). While optimality models predict that humans will trend toward optimization, it is expected that they will never truly be optimal because of lag times between environmental changes and adaptations (Foley 1985; Hames and Vickers 1982).

Overall, HBE and OFT provide an interpretive framework that can be used to assess what environmental parameters constrained foragers and make predictions about how foragers could respond to those conditions (Foley 1985; Hames and Vickers 1982).

Hunter-gatherers employ various resource use strategies as they move across landscapes with discontinuous resources (Thacker 2000). To adapt to resource inconsistencies, hunter-gatherer groups could attempt to optimize their strategies by making buffers for times of resource scarcity, incongruity, and/or discontinuity. Archaeologists studying lithic technology have often discussed this in terms of “curation”, or how a tool assemblage is maintained (Binford 1979; Nash 1996; Shott 1996). By
applying HBE and OFT to the lithic technological organization framework, archaeologists can better understand how adaptive hunter-gatherer lithic technological behaviors were at a regional level, and what geographic or organizational factors influenced their technological strategies (see Chapters 2, 4, and 5).

4.3 Regional Sampling

This study used a regional (i.e., Vasco-Cantabria) comparative sample in order to assess patterns and variability in Magdalenian human behavior. Lithic assemblages from 11 Magdalenian archaeological sites located in Cantabria and Guipúzcoa provinces were analyzed (Fig. 1.1):

Altamira (Cantabria), a coastal site that is summarized further in Chs. 4 and 5 (Freeman and González Echegaray 2001);

Camargo (Cantabria), a small cave in the Peña del Mazo (the cave’s alternate name) formation in the Cantabrian coastal zone, discovered and excavated by M. Sautuola in 1878. This cave later collapsed (Utrilla 1981). The occupation is attributed to the Magdalenian based on the discovery of an engraved antler baton, along with stone tools and bison, horse, and deer remains, although there remains debate about whether or not the level is Magdalenian or Solutrean in age (Utrilla 1981);

Ekain (Guipúzcoa), which is located in a hilly, coastal zone, with narrow valleys, has Lower Magdalenian (15,400-16,030 uncal. BP) and Upper Magdalenian levels (see Altuna and Merino 1984);

El Juyo (Cantabria), which is described in further detail in Chs. 4 and 5 (Barandiarán et al. 1985);
El Otero (Cantabria), a coastal site in the Río Asón drainage that was discovered by L. Sierra in 1909 and much later excavated by J. Gonzáleze Echegaray in 1963 (González Echegaray et al. 1966). The levels date to the Upper Magdalenian based on their osseous industries, particularly harpoons (González Sainz 1989);

El Mirón (Cantabria), a montane site in the Río Asón valley, which is described in detail in Chs. 3-5 (Straus and González Morales 2012);

El Rascaño (Cantabria), a small, montane site that is described in more detail in Chapters 4 and 5 (González Echegaray and Barandiarán 1981);

Erralla (Guipúzcoa) is located near Ekain in a hilly coastal lowland environment (Altuna et al. 1985). The cave contains Lower and Upper Magdalenian deposits that were excavated by a team led by J. Altuna in 1977 and 1978. Level 5 has been dated to the Lower Magdalenian based on three assays (16,270, 16,200, and 15,740 uncal. BP) and
Levels 1-3 have been dated to the Upper Magdalenian (12,310 uncal. BP);

Hornos de la Peña (Cantabria), is located in a montane zone and was discovered by H. Alcalde del Río in 1903 and thought to be Solutrean or Magdalenian in age (Utrilla 1981). Excavators recovered worked bones and lithic artifacts from the site in small hearth features; these remains are not abundant, representing only ephemeral occupations (Utrilla 1981);

La Pasiega (Cantabria), discovered in 1911 by H. Obermaier in the Monte Castillo cave system, where the important Magdalenian site El Castillo is located (Utrilla 1981). It is also located in a mountainous portion of inner Cantabria. Whether the remains from this level, like those from Camargo and Hornos de la Peña, date to the Magdalenian, Solutrean, or a mixed Solutrean/Magdalenian remains debated based on the lithic industry (see Corchón 1971; Jordá 1955; Utrilla 1981); and

Urtiaga (Guipúzcoa), which is described in Chapter 2 (see Altuna 1972; de Barandiarán 1974, 1979a-d).

While previous research has synthesized results from multiple sites (e.g. González Sainz 1989; Straus 1992; Utrilla 1981), this project employs direct comparisons on a regional level using the same analytic methods. This approach makes it possible to reconstruct landscape-level Magdalenian technological adaptations and their relationship to environmental (i.e., geographical, resource, etc.) complexity.

4.4 Lithic Analysis

4.4.1 Debris Typology

Lithic analysis was based on a debris typology that grouped lithic artifacts into seven general categories: microdebitage, flakes, blades, bladelets, chunks, other debris,
and cores. Table 1.2 provides further breakdown of each debris category by fragmentation, cortex, etc. Microdebitage were defined as any materials less than one linear centimeter in size. Flakes were identified via Hertzian morphology, and distinguished from blades based on absence of parallel sides. Blades and bladelets were defined by at least a 2:1 length:width ratio and parallel sides. Blades were two centimeters or longer, while bladelets were less than two centimeters. Chunks were defined as non-Hertzian angular pieces with no discernable axis. The “Other Debris” category encompasses materials representing special manufacturing techniques (e.g. burination). These artifacts were analyzed in the same manner as flakes. Cores were defined based on the types of removal scars (flake/blade/bladelet) and overall shape. Together, these debris types encompassed the variation typical of Vasco-Cantabrian Magdalenian lithic assemblages.

4.4.2 Lithic Analysis Attributes

Eighteen attributes formed the basis of the lithic analysis. Some are derived from the analytic methodology developed by G.A. Clark and L.G. Straus for the study of lithic artifacts at La Riera cave (Asturias), and as modified in Straus’ subsequent analysis of the Abri Dufaure (Straus [ed.] 1995), various sites in Portugal and Belgium, and finally at El Mirón cave (Cantabria). Additional specialized attributes adopted by Fontes were recorded for cores, tools, and used/ altered lithics. Fewer attributes were recorded in some cases, depending on sampling procedures (explained in section 4.4.4). The basic attributes recorded were:

(1) *Debris category*. See Table 1.2.

(2) *Debris type*. See Table 1.2.
(3) *Raw material.* Raw material reference collections were made for each site and all artifacts (except microdebitage) were compared to these raw material samples and assigned a precise tool stone type.

(4) *Patina.* Patina was recorded as presence/absence. Patina ranged from intermittent white sheen to flints crumbling and becoming chalk-like, depending on the raw material.

(5) *Heat treatment.* Heat treatment was recorded as presence/absence. Pot-lidding and crazing were considered evidence for lithic heat treatment.

(6) *cm$^2$ size.* Lithics were sized using a cm$^2$ size chart. Sizing was based on whether or not two dimensional artifact area could fit within the bounds of progressively larger cm$^2$ boxes (1cm$^2$, 2cm$^2$, 3cm$^2$, etc.). If an artifact was longer than the bounds of a cm$^2$ box, but could be “cut” along the cm$^2$ box line such that the extraneous area could still fit within the box, the artifact was classified as the smaller cm$^2$ size, rather than size of the overflow quadrant. If extraneous area was unable to visually fit within the smaller size, the artifact was given the next largest cm$^2$ size.

(7) *Weight.* The weight of the artifact(s) to the nearest 0.1 gram.

(8) *Count.* The number of artifacts.

(9) *Portion.* The portion of each individually analyzed artifact was identified as proximal, mesial, distal, longitudinal, unknown, or whole. An artifact with a complete platform and a termination was considered whole. Artifacts that were partial in portion (distal, longitudinal, etc.) were considered fragmentary. All chunks and cores were classified as whole.

(10) *Dorsal scar count.* Dorsal scar counts were measured on a 0-3 scale, where:
0 indicated no previous removals on the exterior surface; 1 represented one removal; 2, two removals; and 3, three or more previous removals (following Andrefsky 2005).

(11) Cortex presence/absence. If cortex was present on any portion of the artifact, cortex was marked “present”. Plain artifacts were marked “absent”.

(12) Cortex percent. Cortex percentage was measured using a scale: 0 indicated no cortex; 1 represented cortex coverage on less than 1/3 of the dorsal face; 2 marked cortex coverage on between 1/3 and 2/3 of the exterior surface; and 3 denoted cortex coverage on greater than 2/3 of the outer surface.

(13), (14), and (15) Length, Width, and Thickness. Length, width, and thickness measures were recorded based on the axis of the piece, with length being the platform-termination measure, width perpendicular to length, and thickness at the imaginary cross formed by length and width measures. For pieces with no axis, length was a measure of the longest edge and other measures were made with respect to length as they would be if the piece had an axis. For cores, axis was determined based on core directionality from the last removal made; metrics were measured based on the length of the core axis. All measures were rounded to the nearest millimeter (i.e., 11.4 rounds to 11; 11.5 rounds to 12).

(16) Platform type. Platforms were classified as flat, abraded, cortex, or complex (following Andrefsky 2005).

(17) Termination type. Terminations were recorded as feather, step, hinge, axial, or overshot (following Cotterell and Kamminga 1987).

(18) Use presence/absence. If an artifact showed signs of edge damage when analyzed with a 10x hand lens (see attribute 20), use was marked as “present”. Materials
with no edge damage were marked “absent”.

The specialized attributes recorded were:

(19) *Use location.* Lithic alteration was qualified in up to four separate locations on an artifact. These locations were distinguished as: proximal, distal, right, left, platform, or other (for materials with no axis).

(20) *Use type.* For each use location recorded, the type of edge damage identified was classified as: (a) continuous or discontinuous; and (b) nibbled, dulled, a flake snap, edge concavities (half moons), or abraded.

(21) *Tool type.* Tools were classified using the de Sonneville Bordes and Perrot (1954, 1955, 1956a, 1956b) Upper Paleolithic tool typology. Up to three classifications were made for a single tool, if applicable.

(22) *Platform number.* The number of platforms on a core.

(23) *Number of removals.* The number of removals made from all core platforms (cumulative).

(24) *Removal termination type.* The number of removals that ended in hinge or step terminations (also cumulative).

4.4.3 Application of Attributes

Attributes were recorded differentially based on whether lithics were microdebitage, fragmentary debris, whole debris, chunks, tools, and cores. Additional distinctions were made based on sampling procedures and whether or not lithics were analyzed individually or aggregately (described in the next section). Table 1.3 conveys which attributes were analyzed based on whether or not artifacts were microdebitage; whole or fragmentary flakes, blades, bladelets, or other debris; chunks; cores; and tools.
The largest analytic distinction lies among whole and fragmentary flakes and chunks. Fragmentary materials and chunks were not subject to metrics or dorsal scar counts; platform and termination types were only recorded for fragmentary debris if they were present.

4.4.4 Sampling

Hierarchical sampling procedures were used to analyze lithic artifacts from Vasco-Cantabrian Magdalenian sites. Three tiers were used, referred to as:

(1) *All Attribute Individual Flake Analysis (AIFA)*, a detailed individual artifact analysis (used to analyze materials from Altamira, Camargo, Ekain, El Juyo, El Otero, El Mirón, El Rascaño, Erralla, Hornos de la Peña, La Pasiega, Urtiaga; see Table 1.3);

(2) *Reduced Attribute Flake Analysis (RAFA)*, an individual artifact analysis that excluded some qualitative and quantitative variables included in AIFA (used in analyses of El Juyo, El Mirón, El Rascaño and Urtiaga, see Table 1.4); and,

(3) *Aggregate Analysis (AGG)*, a collective lithic analysis wherein minimal attributes were recorded (used in analyses of El Juyo and Urtiaga; Table 1.4). Table 1.4 summarizes the attributes recorded in RAFA and AGG analyses; RAFA is shown using three columns that account for analytic distinctions made for whole, fragmented, or non-Hertzian lithics, as each group was analyzed slightly differently. AGG analysis did not distinguish between fragmentary and non-fragmentary debris and clustered debris types together based on their category (i.e., flakes, blade(let)s, chunks, burin spall, etc. shown in Table 1.2). Cores, tools, and microdebitage were always analyzed following the AIFA guidelines shown in Table 1.3 regardless of which sampling system was used for the rest of the lithic debris.
The lithic assemblages from Altamira Level 2, Camargo, Ekain Levels 6 and 7, El Otero Levels 1-3, El Rascaño Level 4, Erralla Levels 1-3 and 5, La Pasiega, Hornos de la Peña, and Urtiaga E and F were all analyzed using the AIFA procedure. RAFA procedures were used to analyze El Rascaño Level 4B. At El Mirón, RAFA was used to analyze two spits in Level 16 and six spits in Level 17; in these cases it was balanced with AIFA at a 50/50 ratio. For El Juyo, where the sampled area was 30 square meters for level 4 and 15 square meters for level 6, combinations of all three sampling procedures were determined for each meter square based on the number of artifacts in the unit. Squares with greater artifact densities used higher percentages of AGG and RAFA analyses and lower percentages of AIFA; in contrast, low density squares were sampled with all-AIFA or mostly-AIFA procedures. Aggregate analysis never composed more than 50% of a sample, ensuring that most artifacts from each level were analyzed individually. Approximate sampling procedure percentage breakdowns by square for El Juyo levels 4 and 6 are shown in Figs. 1.2 and 1.3, respectively. For the extraordinarily large El Juyo assemblages, AIFA, RAFA, and AGG procedures were used in combination to enable complete sampling of each level’s contents and to ensure that detailed information was collected from every excavation unit such that through further analysis, spatial comparisons can be made within the Juyo vestibule. Finally, AIFA, RAFA, and AGG procedures were also used in combination (25% AIFA, 25% RAFA, and 50% AGG) to analyze Urtiaga Level D, sectors 1-5.

4.4.5 Lithic Raw Materials

Lithic raw materials were analyzed following the procedure described in section 2.4 above. Lithic toolstones were visually distinguished based on several attributes: color,
and any variations therein; homogeneity; grain size; texture; inclusions, including size/character; matte or sheen; opacity; patina; fracture type (conchoidal, orthogonal, etc.); and cortex color and texture (i.e. rounded river cobble, weathered, etc.). See
Appendix C.

4.4.6 Frameworks and Methods Summary

This project used debitage, an underutilized data source in Upper Paleolithic archaeology, as a primary data source from a regional sample of Magdalenian sites to broaden the lens through which archaeologists can interpret past human behavior during this period. The debitage-based analyses used in this study (aggregate, individual, low-magnification use wear, etc.) are easily replicable by other Paleolithic archaeologists whose work is focused in Vasco-Cantabrian Spain or beyond it. These methods have the potential to become widespread and can be used to analyze and interpret materials from any site wherein modern archaeological excavation and recovery techniques have been employed. Chapter 2 also illustrates how these techniques can bring new perspectives to collections that were recovered using now outdated archaeological methods. Debitage provide information that archaeologists can use to infer prehistoric lithic technological organization, which in turn enables a more detailed understanding of Last Glacial human behavioral adaptations at a landscape level than inter-site comparison of lithic tool types (the analytic standard) can provide. This approach makes this study unique in its ability to reconstruct an economic baseline that archaeologists can use to better frame other behaviors documented during this period (e.g., hunting strategies, aggregations, etc.).

5. Dissertation Summary

This hybrid dissertation uses approaches framed by lithic technological organization and Human Behavioral Ecology to explore human adaptations to environmental complexity during the Last Glacial period. Five manuscripts are presented here: I am the sole author of the manuscript presented in Chapter 2, and the first author
on the collaborative manuscripts in Chapters 3-5. I accomplished the hypothesis formulation, data collection, data analysis, and primary writing of the research presented here. Each dissertation chapter is summarized below with a brief abstract.

Prehistoric transitions are of broad interest to archaeology. Chapter 2 discusses one transitional “moment” in prehistory: the Solutrean-Magdalenian transition. Immediately following the Last Glacial Maximum, two technological shifts occurred in southwest Europe. First, in France, at c. 18,000 uncal. BP, an industry characterized by large Solutrean projectiles was replaced by the well-defined Badegoulian industry. Second, a thousand years later in Vasco-Cantabrian Spain, Solutrean technologies were gradually replaced by Magdalenian antler point (sagaie) and lithic insert composite weapons. The transition from Solutrean to Magdalenian technologies remains poorly defined in Vasco-Cantabria, where few “transitional” assemblages dating to c.17,000-16,000 uncal. BP have been identified (notably at El Mirón and nearby El Rascaño caves). This paucity of data has left archaeologists with questions as to how changes occurred between the Solutrean and Magdalenian, including what kinds of relationships may have existed between Spanish and French groups at this time. Urtiaga cave (Guipúzcoa) Level F (17,050+/-140 uncal. BP) contributes a new Initial Magdalenian archaeological sample to the discussion of Last Glacial behavioral change during a technological transition. Chapter 2 synthesizes the results of a detailed lithic analysis with findings from previous studies of fauna and osseous industry from Urtiaga Level F. Then, the analysis explores Initial Magdalenian organizational behaviors through a series of lithic procurement/mobility models that show dynamic land use in eastern Vasco-Cantabria. Finally, Urtiaga Level F was compared to four other Initial Magdalenian occupations in
the region, demonstrating that lithic maintenance—in manufacture, use, and rejuvenation—was a significant factor in how Initial Magdalenian groups organized their landscape-level behavioral strategies. The archaeological assemblages from Urtiaga cave are important contributions to archaeological questions surrounding the Solutrean-Magdalenian transition, providing further evidence for in situ technological change in Vasco-Cantabria. Additionally, the economic analyses discussed in Chapter 2 provide new attributes that archaeologists can use to identify Initial Magdalenian sites on the landscape. This study develops a methodological procedure that is broadly applicable to archaeological studies related to prehistoric cultural transitions and to those studies that apply data from collections recovered during the early 20th century to modern interpretive frameworks.

Chapter 3 presents a preliminary summary of lithic and osseous artifacts recovered from El Mirón cave Level 504, whose ochre-stained sediments were associated with a Lower Magdalenian human burial. The lithic artifacts recovered from Level 504 were mainly concentrated immediately to the south of the area of concentrated human remains. These debris indicate that lithic manufacture in this area focused on end-stage bladelet production that followed preparatory blade and flake removals. The lithic assemblage is rich in Lower Magdalenian diagnostic artifacts, especially bladelet tools that were made on very high-quality flints. The osseous industry (principally antler sagaies), is highly fragmented but consistent with others known from El Mirón cave. The lithic and osseous industries recovered from Level 504 are typical of the Lower Magdalenian in Cantabria province, Spain. The Level 504 artifacts were recovered from a context with a significant amount of microstratigraphic variation that was associated with
both natural and cultural formation processes. It is unknown how extensively these 
materials were spatially and/or temporally displaced from their primary discard locations 
when Level 504 was deposited. When these artifacts are interpreted as a single unit and 
compared with those from the underlying Level 505, the burial area materials indicate 
spatial continuity with the similarly rich (and radiometrically contemporaneous) Lower 
Magdalenian occupations identified in the El Mirón cave mid- and outer vestibule into 
the vestibule rear (Levels 109, 312, and 17). The artifacts found in Level 504 provide 
further evidence that testifies to El Mirón’s importance as a major Lower Magdalenian 
residential site in the montane zone of the Cantabrian region. The lithic artifacts 
summarized in this article constitute the sample from El Mirón cave that is explored 
further in Chapters 4 and 5.

Chapter 4 discusses Last Glacial mobility in the Vasco-Cantabrian region of north 
coastal Spain. Hunter-gatherer groups’ organizational strategies were influenced by how 
key resources, including lithic toolstones with fixed outcrop locations, were structured on 
landscapes. Lithic artifacts are ideal for landscape-level behavioral reconstructions 
because they are created via reduction sequences. Consequently, archaeologists propose 
that toolstone decreases in quantity in mobile assemblages as groups move further from 
lithic sources. Reduction stages for lithic raw materials can be determined using 
diagnostic lithic debris (e.g. primary cortical pieces, platform renewal flakes, and cores). 
By comparing lithic raw materials and their reduction stages at four Lower Cantabrian 
Magdalenian sites (Altamira, El Juyo, El Mirón, and El Rascaño), Chapter 4 reconstructs 
lithic provisioning and hunter-gatherer mobility in the center of the Vasco-Cantabrian 
region during the Last Glacial period. This case study proposes that the Lower
Magdalenian groups who occupied these sites shared an economic territory that extended from Cantabria into western Navarra and conveyed toolstones between sites as part of mobile toolkits. Local raw material conveyance demonstrates that shifting environmental zones was an important factor in these hunter-gatherer mobility strategies in Cantabria. Lower Magdalenian hunter-gatherers used environmental complexity to their advantage as they traversed the Cantabrian landscape.

Chapter 5 uses a mathematical model for toolstone production efficiency to explore Lower Magdalenian toolstone procurement, mobility, and toolkit management. The results of this case study indicate that the most efficient lithic raw materials were those used for bladelet production. Hunter-gatherer groups conveyed the toolstones with the greatest potential production efficiency across the landscape in mobile toolkits, procuring less efficient stones locally to hedge against depleting the most productive materials. Chapter 5 explores how groups may have moved to procure highly efficient toolstones, either via exchange with other groups or via territorial adjustments within a large, habitual range. This chapter explores the influence that heterogenous Vasco-Cantabrian lithology may have had on Lower Magdalenian lithic organizational strategies.

Each case study presented in Chapters 2-5 contributes new data to archaeological understanding of how human groups adapted to environmental complexity during the Late Last Glacial. While figures have been embedded in the text in each of Chapters 2-5, data tables and supplements have been placed at the end of each chapter for ease. Acknowledgements specific to each manuscript have been placed at the end of their corresponding chapter. Additionally, all references cited in each of Chapters 2-5 have been collated into a single bibliography placed at the end of this dissertation. Finally,
Chapter 6 summarizes this dissertation and situates it in broader anthropological context.

Following the main text and bibliography, this dissertation includes several appendices with summary data collected during a two-year research period in Spain.

**Table 1.1 Lithic Samples Analyzed as Part of this Study**

*Time periods are abbreviated as follows: Solutrean (S); Initial Magdalenian (IM); Lower Magdalenian (LM); Middle Magdalenian (MM); Upper Magdalenian (UM); Azilian (AZ); Unspecified Magdalenian (M). Zone refers to environmental location within Vasco-Cantabria. Environmental zones are abbreviated as follows: littoral (L); hilly coastal lowland (H); and montane (T).*

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**Total Analyzed** 331,238
**Table 1.2** Types of Lithic Debris Identified in Analysis

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Table 1.3. Attributes by Debris Type
Abbreviations: *microdebitage (MD), fragmentary debris (FD), and whole debris (WD).
*Platforms and terminations were only recorded if that portion of the fragment was present. Attribute analysis shown here is based on AIFA sampling procedures.

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**Table 1.4.** Attributes Recorded in RAFA and AGG Sampling Procedures

*Abbreviations: fragmentary debris (FD), and whole debris (WD).*

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Chapter 2: 
The Initial Magdalenian Mosaic: New Evidence from Urtiaga Cave, Guipúzcoa, Spain

This chapter is a manuscript written by Lisa M. Fontes that is published in 2016 in the *Journal of Anthropological Archaeology*, volume 41, pages 109-131.

Introduction

Archaeologists have a longstanding interest in understanding continuity and change, stemming from the work of the discipline’s early culture historians who created chrono-cultural technocomplexes as a way to describe prehistoric behavioral shifts. These units have a legacy in modern archaeology: researchers are still asking how cultural traditions changed and what factors influenced the material culture variations recognized in each period (see examples in Cascalheira and Bicho 2013; Schmidt et al. 2012; Straus 2015). One challenge that archaeologists face is how to utilize archaeological collections that were recovered long ago, without the precision of modern excavation and recording techniques, and incorporate these data into modern interpretive frameworks. This case study approaches a particular chrono-cultural transition in prehistory, the Solutrean-Magdalenian interval c. 18-16,000 uncal. BP, using a multi-faceted and broadly applicable methodology that incorporates materials (lithic, osseous, and faunal) analysis with spatial and landscape modeling and inter-site comparisons.

In the Upper Paleolithic period, the first material culture analyses at the turn of the 20th century used “type” sites to characterize the artifact variations that marked particular culture-historical divisions (e.g., Solutrean at Solutré and Laugerie-Haute, Magdalenian at La Madeleine and Laugerie-Basse). In the past fifty years, excavations that employed modern techniques, including water-screening and radiocarbon dating,
have revealed that regional geographic variation (e.g., lithology, available comestible resources, environmental patches) substantially affected Upper Paleolithic technology in Vasco-Cantabrian Spain, and by proxy, how archaeologists made culture-historical attributions and compared Spanish and French lithic and osseous industries (Barandiarán et al. 1985; Freeman et al. 1998; González Echeagaray 1960, González Echeagaray and Barandiarán 1981; Straus 1992, 2005). This work has shown that while groups who lived in France and Spain traveled similar trajectories in having to deal with major climatic shifts throughout the Upper Paleolithic, important differences in lithic technologies, subsistence strategies, art motifs, and chronology led to distinct regional “expressions” of these western European archaeological cultures (Aura et al. 2012; Banks et al. 2009; Straus 1992, 2005, 2013; Utrilla 1981).

Advances in archaeological techniques have also provided archaeologists a more precise lens through which to view technological developments and their co-occurrence with climatic shifts and ensuing environmental change (Schmidt et al. 2012). Immediately following the Last Glacial Maximum, c.18-16,000 radiocarbon years uncal. BP, when the western European climate was gradually and unevenly beginning to warm, large, “expensive” Solutrean point technology was replaced by “maintainable” composite antler point and microlith insert projectiles (see Bleed 1986; Straus 1991, 1993). In the past two decades, researchers working in Vasco-Cantabria and southwest France have identified many sites with “intermediate” assemblages that date to the Solutrean-Magdalenian transition. In France, this transition is marked by the Badegoulian industry, whose assemblages are typically raclette-rich (but see Clottes et al. 2012) and generally versatile in addressing tool blank production needs (i.e., thick and thin flakes) (Ducasse
In contrast to the well-defined Badegoulian industries, the Solutrean-Magdalenian transition in Vasco-Cantabria is marked by very few occurrences of so-called Initial Magdalenian assemblages dating to c.17,000 uncal. BP: El Rascaño Level 5 (Cantabria), El Mirón Levels 117-119.3 (Cantabria), and now, Urtiaga Level F (Guipúzcoa); and chronologically late Solutrean levels: La Riera 17 (Asturias); Las Caldas Pasillo 4 (Asturias); Chufín (Cantabria); Aitzbitarte IV (Guipúzcoa) and Arlanpe II (Vizcaya) (Altuna 1972; Aura et al. 2012; Corchón 1999; González Echegaray and Barandiarán 1981; Straus 1983; Straus and Clark 1986; Straus et al. 2014; Rios-Garaizar et al. 2013). Thus, the Solutrean-Magdalenian transition is not nearly as well documented in northern Spain as it is in France, making it difficult to understand exactly how this technological change occurred, specifically, whether it was the result of gradual in situ adaptations to organizational strategies or more drastic cultural shifts (see Bosselin and Djindjian 1999). This paper presents results from Urtiaga Level F lithic analyses and synthesizes these findings with those from previous studies of osseous industry (Mugica 1983) and faunal remains (Altuna 1972) from the level, thoroughly describing the Initial Magdalenian occupation at this location. This analysis then explores Initial Magdalenian land use through a series of mobility/lithic procurement models. In synthesis, Urtiaga Level F is compared to four other archaeological levels dating to c.17,000 uncal. BP in order to address what organizational aspects contributed to the Solutrean-Magdalenian technological shift in Vasco-Cantabria. Together, these contexts demonstrate that assemblage maintenance—in manufacture, use, and rejuvenation—was an important aspect of Initial Magdalenian lithic technology. Additionally, the Urtiaga cave assemblage contributes to archaeological understanding of
the Solutrean-Magdalenian transition in Vasco-Cantabria, providing further evidence of
in situ regional “desolutreanization” and economic attributes that archaeologists can use
to recognize Initial Magdalenian contexts. This study is broadly analogous to
archaeological research in Europe and other world regions related to: (a) understanding
changes between cultural-historical units against the backdrop of major climatic changes
(in this case, from the Last Glacial Maximum to the Oldest Dryas within MIS 2) and/or
(b) applying data collected from assemblages that were recovered using early recording
systems to modern interpretive frameworks.

The Solutrean-Magdalenian Transition

How archaeologists investigate Upper Paleolithic archaeological cultures has been
influenced both by long term research histories (i.e. the archaeological record from this
period in the Vasco-Cantabrian region has been under-researched relative to the same
period in France, due in part to early chrono-cultural systematization by French
prehistorians (notably H. Breuil, D. Peyrony and D. de Sonneville-Bordes) who then
sometimes applied their temporal systems on the Spanish record) and by regional
cultural-historical trajectories (Straus 2013, 2015). Despite the fact that archaeological
cultures in the Franco-Cantabrian region (the Vasco-Cantabrian northern Spanish coast
and the southern Aquitane) share some common lithic and osseous artifacts and artistic
similarities at various points in the Upper Paleolithic chronology (e.g., during the Upper
Magdalenian), there are major differences in these two landscapes (Straus 2015). While
mountain chains and coasts geographically bound both areas (Vasco-Cantabria by the
Picos de Europa and Cantabrian Cordillera to the south, the Bay of Biscay to the north;
Aquitane by the Pyrenees to the south and Massif Central to the north, the Atlantic Ocean
and Mediterranean Sea to the west and east, respectively), the Vasco-Cantabrian region is characterized by short, steep river valleys with diverse local environments, while the Aquitane had great plains with steppe-tundra vegetation during the Oldest Dryas (Straus 2015). These environmental differences—including terrain, lithology, vegetation, and comestible resources—no doubt influenced how the human groups who inhabited these areas organized their territories, their mobility and subsistence strategies, and the unique regional cultural trajectories that developed in each area throughout the Upper Paleolithic (Straus 2015). The Solutrean-Magdalenian transition is one cultural-historical “moment” where the hunter-gatherer groups living in western Europe took separate paths (Straus 2013). In the Vasco-Cantabrian region, the transition can reasonably be summarized by the following chronological trajectory (Straus 2015):

- Solutrean: 21,000 – 17,000 uncal. BP;
- Initial Magdalenian: 17,000 – 16,000 uncal. BP;
- Lower Magdalenian: 16,000 – 14,300 uncal. BP.

By comparison, the French Badegoulian archaeological culture dates to c.18,200 – 16,500 uncal. BP (Banks et al. 2011).

The Solutrean period is archaeologically known by its large, single-lithic tip projectile weaponry, which was likely used as a component of atlatl-propelled or thrusting spears (Straus 1992, 2005, 2009). In Vasco-Cantabria, the period is also known for its evidence of situational subsistence specialization, with groups killing red deer and ibex in their respective habitats (coast and montane) and overall diversification, with incidences of hunters taking boar, reindeer, fox, and roe deer, probably opportunistically, to such extent that Straus and Clark (1986) called it an early “broad spectrum revolution”.
As the Solutrean period progressed, hunter-gatherer groups developed diverse regional projectile point styles (e.g., shouldered or concave base)—and perhaps also distinct regional identities—that may have in turn influenced their social organization, ideology, territoriality, and (reduced) interaction networks (see Aura et al. 2012; Banks et al. 2009; Straus 1983; Tiffagom 2006; Rasilla Vives 1989, 1994; Villaverde and Fullola 1990; and Zilhão 1997). These Solutrean regional shifts may have been a key factor in the development of separate Badegoulian and Initial Magdalenian archaeological cultures in France and Spain, respectively (Aura et al. 2012; Banks et al. 2009).

The Badegoulian archaeological culture is principally recognized by diagnostic raclettes—quadrangular lithic artifacts made on flakes with near-parallel faces and generally backed on all or several sides—and by assemblages that indicate flexible tool-blank production (Banks et al. 2011; Ducasse 2012; Ducasse and Langlais 2007; see also Clottes et al. 2012). Since the raclette is a lithic tool type that is very common only in the Badegoulian, it has been used to define the spatiotemporal extent of this industry (Banks et al. 2011). Transverse burins are also common in some Badegoulian assemblages, but seem to be less diagnostic as “fossil directors”. Despite considerable debate about the presence/absence of Badegoulian industries in the Iberian Peninsula and central Europe based on archaeological assemblage attributes (see Aura Tortosa 2007; Bosselin and Djindjian 1999; Straus and Clark 2000; Terberger and Street 2002; Zilhão 1997), the data do not convincingly indicate that the Badegoulian culture extended beyond modern-day France (Banks et al. 2011). Archaeologists have argued that the Upper/Final Solutrean regional territories were essential to how the Badegoulian developed and was maintained (see Banks et al. 2011). Additionally, the reduced inter-group social contacts at the
Upper/Final Solutrean—Badegoulian juncture in France could relate to why archaeologists have recovered scant evidence of characteristic Badegoulian artifacts (especially raclettes and transverse burins) in Initial Magdalenian contexts (Straus 2013): there may have been very little contact between groups in these two regions at this time.

Due in part to the still-limited Initial Magdalenian archaeological record, the nature of the Solutrean-Magdalenian transition in Vasco-Cantabria is still the subject of considerable debate. Archaeologists generally agree that the process was a gradual one, wherein Solutrean lithic projectiles were replaced by the antler sagaie and lithic inset composite systems common in the Lower Magdalenian period (Corchón 1981, 1984; Straus 1983, 2000, 2013; de la Rasilla and Straus 2006). Archaeologists have also noted other characteristics of Initial Magdalenian assemblages: “mixed” weaponry assemblages, some “archaic” tool types (notches, denticulates) made on local non-flint raw materials (though this characteristic varies, perhaps as a consequence of local lithology), and osseous industries that include very large antler sagaies (Aura et al. 2012; Straus and Clark 1986; Straus et al. 2014). Of course, these assemblages have also been identified through stratigraphic contexts: underlying well-defined, rich Lower Magdalenian levels and overlying equally diagnostic, projectile-rich Solutrean ones (Straus 2015). Unlike the Badegoulian, with its fossil director—the raclette—the Initial Magdalenian cannot be defined by a single artifact, and is thus recognized by its transitional nature: it was a variable shift from the preceding Solutrean (Straus 2015). This “desolutreanization” has been documented at several sites (e.g. La Riera, Las Caldas, El Mirón), and occurred approximately 1,000 years after the Badegoulian industries swept through France (Corchón 1994; Straus 1983, 2015; Straus and Clark 1986; Straus et al. 2014).
Thus, while it is widely accepted that there was some degree of continuity between the Solutrean and Initial Magdalenian (see Aura 2007; Corchón 1981, 1994; Straus and Clark 1986; Rasilla Vives 1994; Rasilla Vives and Straus 2006; Straus 2015), the relationships that existed between the Upper Solutrean, Badegoulian, and Initial Magdalenian were complex ones (Aura et al. 2012). It is possible that the Initial Magdalenian trajectory known in Spain was a cultural choice, that hunter-gatherer groups selected maintainable technologies without making other adaptive changes. For example, at El Mirón cave (as at other sites such as La Riera), the Solutrean-Magdalenian transition occurred without a corresponding subsistence shift: red deer, ibex, and salmon remained the principally exploited comestible resources at the site from the Solutrean through the Magdalenian (Straus et al. 2014; Straus 2015). It is also possible that the differing Badegoulian/Initial Magdalenian trajectories related to demographic dynamics: the changes could have been influenced by territorial/site distributions initiated in the Upper Solutrean (Aura et al. 2012; Straus and Clark 1986). Recently, archaeologists have used multi-dimensional models to explore these hypotheses (see Banks et al. 2009, 2011).

This paper also explores the Solutrean-Magdalenian transition using a multi-faceted approach, focused on the assemblages recovered from Urtiaga cave, which are a window to how environmental and social factors may have influenced Initial Magdalenian regional adaptations.

Urtiaga Cave

Geographic and Lithological Setting

Urtiaga cave is located in the barrio of Itziar, Deva, Guipúzcoa (Basque Autonomous Region), on the SSW slope of Salbatoremendi hill at 43°16’55” north
latitude and 2°18’55” longitude west of the Greenwich meridian (Fig. 1; Altuna 1972).
The cave vestibule looks over a small valley that is situated between the Deva and Urola river drainages. The site is 130 meters above sea level and is a linear distance of 1.5 kilometers from the present day coast, perhaps an additional 10-15km from the Last Glacial coast (Altuna 1972). Urtiaga is located in an area rich in limestone mountains and escarpments, including the geographically closed Lastur basin and the Izarriatz-Erlo massif (elevation 1026m) to the south. The landscape is dramatically mountainous with substantial elevational variation in short distances and in some sectors of the coast, very striking cliffs (Fig. 1 inset). During the Final Solutrean, c.18,000 uncal. BP, the Greenland Stadial 2 (Wurm IIIb) climate in Vasco-Cantabria was both cold and dry, gradually fluctuating to cool and humid during the Laugerie and Lascaux interstadials between 18,000 and 15,000 uncal. BP, when the Initial Magdalenian occurred. By 15,000 uncal. BP, when Lower Cantabrian Magdalenian (LCM) groups inhabited Vasco-Cantabria, Dryas I brought cold and slightly humid conditions to the region (Altuna 1972; Hoyos 1995). As a consequence of these climatic shifts, Urtiaga cave’s Initial Magdalenian occupants would have known a diverse environmental patchwork: grass-and heathlands, slowly expanding woods, and barren north-facing slopes with the remnants of montane glaciers (Hoyos 1995; Pokines 1998; Straus 1992). From this location, hunter-gatherers would have been able to easily access comestible resources provided by two river valleys and the sea (fish and shellfish), montane ridges (ibex), and geographically circumscribed lowlands (red deer), undoubtedly making the cave an attractive settlement location.
Fig. 1. Map of eastern Vasco-Cantabria showing location of Urtiaga and nearby Upper Solutrean (US) and Initial Magdalenian (IM) sites: (1) Aitzbitarte IV (US, Guipúzcoa), (2) Arlanpe (US, Vizcaya), (3) El Mirón (IM, Cantabria), and (4) El Rascaño (IM, Cantabria); and raw material outcrops: (1) Chalosse, (2) Bidache, Microcrystalline, and Chalcedonic flysch flints (with (6) as a possible alternate outcrop at Kurtzia), (3) Gaintxurizketa flysch flint, (4) Urbasa flint, and (5) Treviño flint.

Archaeopetrology is a growing field in Vasco-Cantabrian Upper Paleolithic research (see Bernaldo de Quirós and Cabrera 1996; González Sainz 1992; Rissetto 2009; Sarabia 1990a, 1990b, Straus et al. 1986, and Tarriño et al. 2014). Urtiaga cave is proximal to several high-quality lithic toolstones (Fig. 1). Gaintxurizketa flysch flint (Campanian, Upper Cretaceous), a very dark brown to black flint that is fine-grained, though not always homogenous, which occurs in brecciated formations near Gaintxurizketa, Guipúzcoa, is the raw material outcrop closest to Urtiaga, c. 40 km away (Tarriño et al. 2014). Urbasa flint (Paleocene) outcrops in the Sierra de Urbasa, NW Navarra, Spain, some 50 km SSE of Urtiaga cave. This flint is generally streaky grey colored, and visually distinguished by macroforaminifera, echinoderms, and microdolomitization (Tarriño et al. 2014). Treviño flint (Miocene) occurs c. 70 km SW of Urtiaga cave in the Miranda-Treviño Depression (Álava, Spain) (Tarriño 2007, 2012;
Tarriño et al. 2014). The toolstone is brown and extremely fine-grained. Several flysch flint outcrops occur c. 100 km to the NE of Urtiaga cave in the Pyrénées-Atlantiques region. These include Bidache (Campanian, Upper Cretaceous), which occurs along the Gaves Réunis and Adour rivers between Bidache and Biarritz, and is visually distinguished by parallel turbidic laminations that appear when the stone patinates. Chalcedonic and microcrystalline flysch flints, which contain distinct fossil echinoderms, also outcrop in this area, though it is possible that there were additional sources of these materials along the now-submerged Basque coastline (Fig. 1). Finally, Chalosse flint outcrops ~150 km from Urtiaga cave, in an Upper Cretaceous marine carbonate platform in southern Les Landes, southwest France (Tarriño et al. 2014). This toolstone is typically translucent grey/black, but when patinated it has yellowish-whitish patches. The flint also has many bioclastic inclusions, including *Lepidorbitoides* sp., a macro-foraminifer that is easily recognizable (Chalard et al. 2010; Tarriño et al. 2014). Each of these lithic raw materials has been identified in archaeological sites throughout the Vasco-Cantabrian region because of its unique visual characteristics (Corchón et al. 2007; Fontes et al. in press; Tarriño 2000, 2006, 2012; Tarriño an Aguirre 1997; Tarriño and Normand 2002; Tarriño et al. 2013, 2014). Additionally, several of these visually distinct toolstones (Bidache, Chalosse, Treviño, and Urbasa), are considered tracer flints that archaeologists have used to reconstruct prehistoric territories and networks (Chalard et al. 2010; Fontes et al. in press).

*Excavation and Dating*

ten meters in length and only 1.2 meters width (Barandiarán 1978a). Barandiarán began excavating the following day with T. de Aranzadi, and continued to work at the site from 1928-36, then again after the war in three additional campaigns (Barandiarán and Elosegui 1978). Eleven sectors were excavated, numbered sequentially from the cave entrance (Fig. 2); the first eight removed in the earlier campaigns and the latter three in the recent excavations (Barandiarán 1978a-d). As the upper levels were removed, they revealed a much longer interior gallery that had been blocked by a stalactite formation (Fig. 3); a stalagmitic surface underlies the lowest archaeological levels (Altuna 1972).

Barandiarán took detailed notes of important finds, depths, etc. during the excavations (see Barandiarán 1978a-d). He distinguished 13 archaeological levels in Urtiaga (Fig. 4), identifying the location as one of the most important Upper-Final Magdalenian sites on the Cantabrian coast, located at a crossroads between the areas settled in Asturias and Cantabria and those inhabited in the Pyrenees, including Mas d’Azil (Altuna 1972, Barandiarán 1974, 1978a-d, 1979).

From the earliest excavations, Urtiaga Level F was poorly defined, located underneath the impressive, in some areas over two meter thick, Upper/Final Magdalenian Level D. Barandiarán initially considered Level F, only some 50 cm thick, though nearly a meter in the rear sectors of the vestibule, to be Aurignacian in age. A later partial study of the lithic toolkit conducted by Barandiarán and D. de Sonneville-Bordes (1964) diagnosed the level as another Upper Magdalenian component based on its statistical tool type distribution. Altuna (1972) consulted J.M. Merino about the lithic toolkit; Merino felt there were clear differences between Levels D and F, citing that based on his small study of the materials Level F contained a flake-dominated lithic industry, while Level D
Fig. 2. Urtiaga cave plan view drawings following Barandiarán (1978a) (left) and Barandiarán and Elosegui (1978) (inset image). Points “A” and “B” in the inset plan view correspond to those presented in the cave cross section view in Fig. 3.

Fig. 3. Cross section view of Urtiaga cave showing excavated area and major features (from Barandiarán and Elosegui (1978)). Features (from left to right) include: area excavated in sector 11; location of a human crania found in 1936; major stalactites; boundary of level D; the location of a large boulder unearthed in sectors 6-7 (also shown in the inset image of Fig. 2); the natural chimney (also shown and labeled “F” in the Fig. 2 inset image); and the modern day cave entrance.
Fig. 4. Urtiaga cave partial stratigraphic profile, drawn following Barandiarán (1978a). Numbers above Level A indicate the approximate locations of each excavated sector. A dotted line indicates materials removed before and after 1936.

had more equal proportions of blade and flake debitage. Altuna (1972) additionally noted that Level F’s radiocarbon date, 17,050 +/- 140 uncal. BP (GrN-5817), placed this occupation well before the Upper Magdalenian.

However, the cultural determination of Level F remained disputed. Following Altuna’s (1972) analyses, Barandiarán (1973) remarked that the level could be considered a Lower Cantabrian Magdalenian (LCM) that was slightly older than other occurrences of this type in the Vasco-Cantabrian region. Later, Barandiarán and Utrilla (1975) affirmed that there were some elements in the osseous industry from Level F that were attributable to the LCM, including tectiform engravings on an antler sagaie. Later, Utrilla (1976) proposed that the materials could be from an earlier moment in the Magdalenian chronology, perhaps a Magdalenian II (in Breuil’s [1912] stage system), with some functional differences that distinguished it from other sites. In her 1981 monograph, Utrilla presented the level as one with an industry that was poorly defined archaeologically, neither confirming nor denying whether the component pertained to the
LCM or to an earlier Magdalenian occupation (but also see her more recent views of the nuances within the Urtiaga Level F assemblage in Utrilla 1989, 1994, 1996, 2004; and Domingo et al. 2012)

In the 30 years since Utrilla’s (1981) seminal work, relatively little analysis has been done of Urtiaga materials. J. Mugica (1983; also spelled “Mujika”) studied Urtiaga Level F’s osseous industry as part of his regional study; among the 65 pieces in this collection (of which he studied 56), he identified only a few objects that he felt could sensibly be attributed to the LCM, the rest were inconclusive as to their provenance. Later, Mujika and Peñalver (2012) renewed the stratigraphic profile that remained from Barandiarán’s last excavation in Sector 11 (the profile they made, and thus its exact correlation to Barandiarán’s work, remains unpublished), and published several radiocarbon dates from Level F. Two were from an arbitrary spit in contact with Level E, a more recent deposit (15,620 +/- 290 and 15,530 +/- 70 (I-14,858 and GrA-28317, respectively). However, in the lower part of Level F assays returned two Initial Magdalenian dates: 17,170 +/- 350 (I-16,039) and 17,730 +/- 290 (I-14,857) (Mujika and Peñalver 2012). Thus, an Initial Magdalenian (or Solutrean-Magdalenian transition) age occupation has thrice been demonstrated by radiocarbon dates, though not definitively in discussions of Level F’s archaeological remains (fauna, osseous industry, lithics, etc.). In part, this is due to when these studies were made and how Paleolithic archaeologists temporally characterized industries at particular times (see Straus and González Morales 2012 for a succinct temporal summary). The identification (and widespread acknowledgement among prehistorians) of an Initial Magdalenian period resulted from excavations and analyses (especially radiocarbon dating) made in the late 20th century at
sites in eastern and central Asturias (La Riera, Las Caldas) and Cantabria (El Mirón),
coupled with comparisons of materials from the small-scale 1974 excavation in El
Rascaño Level 5 (González Echegaray and Barandiarán 1981; Straus and González
Morales 2012; Straus and Clark 1986; Straus et al. 2014). That is to say, within the past
two decades there have been major shifts in studies of the Solutrean-Magdalenian
transition and that Urtiaga Level F was not identified as an Initial Magdalenian context is
simply due to the fact that when most studies of its materials were made, this transitional
archaeological “culture” did not exist.

**The Urtiaga F Lithic Assemblage**

*Analytic Methodology*

Lithic artifacts were analyzed individually and classified using a debris typology
that distinguished: microdebitage (<1cm shatter and trimming flakes); whole and
fragmentary cortical and non-cortical flakes, blades (parallel sided and >2cm), and
bladelets (<2cm); chunks (non-Hertzian angular debris); microburins (made using the
notch/snap break technique), burin spalls, platform renewal flakes, splintered pieces, and
uni- and bi-directional crested blades; and flake, prismatic blade(let), pyramidal blade(let),
and mixed cores (modified from Straus et al. 2008). Tools were classified using the de
Sonneville Bordes and Perrot (1954, 1555, 1956a, 1956b) Upper Paleolithic tool typology,
which was modified to include “Juyo” type retouched bladelets as type 90 (instead of
traditional twisted Dufour bladelets, following Barandiarán et al. 1985 as a standard
typological modification for the Vasco-Cantabrian region). Up to three de Sonneville
Bordes and Perrot tool types were used to describe multi-tools that fall into type 92:
“Diverse”. Additionally, a series of qualitative and quantitative attributes that provide
information about all stages of lithic technological organization were recorded for each artifact; these are described in Supplement A.

Assemblage Summary

The Urtiaga Level F lithic assemblage is a total of 1551 artifacts weighing 5762 grams (Table 1). 345 of these pieces were tools. The assemblage was manufactured using 20 visually distinct lithic raw materials: 13 flints, one quartzite, one mudstone/lutite, and five unidentified stones. Seven of the flint raw materials were attributable to geologic outcrops on both sides of the Pyrenees, demonstrating that Initial Magdalenian hunter-gatherers moved lithic raw materials significant distances (>100 km in some cases) (Fig. 1). Only 27 artifacts (1.74% of the assemblage) were burned, a very small portion that does not indicate regular flint heat treatment. The lithic artifacts were relatively large in size (36% were > 2 cm²; Table 2), making them conducive to use: just under a quarter of the assemblage—361 pieces—showed signs of use damage, which was continuous on 299 artifacts and discontinuous on only 62. Nine artifacts showed use damage in multiple locations, though only two lithics were used in three locations. This indicates that while nearly a quarter of the assemblage was modified into formal Upper Paleolithic tool types, sharp flake/blade edges were also utilized as expedient “tools”. The majority of the assemblage (69%) is comprised of whole debris, and an additional 26% of the artifacts are distal portions (Table 2). Other lithic portions are rare. This breakage pattern cannot be attributed to post-depositional trampling alone (otherwise proximal and distal fragments would be more or less equal), thus, it is likely that proximal flake and blade portions were removed from the site as part of a mobile toolkit, as blanks or tools for use in another location. Finally, cortex/reduction ratios for whole debitage indicate very little
cortex (most pieces with cortex have it on less than one third of the exterior surface) and
three or more previous removals (Table 2). Overall, 62% of the assemblage (964
artifacts) is non-cortical. With the closest geographically known source outcrop,
Gaintxurizketa flysch flint, some 40 km from Urtiaga cave (Fig. 1), it makes sense that
Initial Magdalenian foragers would reduce cortical portions of distant raw materials at
settlements located at or nearer to these outcrops in order to reduce transported raw
material weight (see Beck et al. 2002 and associated field processing models: Barlow and
Metcalfe 1996; Bettinger et al. 1997; Bird and Bliege Bird 1997; and Metcalfe and

Debris and Reduction Process

Microdebitage comprise a very small portion (3%) of the Urtiaga Level F lithic
assemblage. It is possible that these artifacts make up such a small portion because of
early 20th century excavation techniques. Though Barandiarán did screen as he excavated,
this process would not have been as rigorous as modern-day water screening operations
typical at Vasco-Cantabrian Upper Paleolithic sites (see Freeman et al. 1998). On the
other hand, even some modern excavations from LCM sites (e.g., Altamira) in the region
have yielded very small portions of microdebitage, which is to say that the small numbers
of trimming flakes may represent behavioral patterns (i.e., little use of hard hammer
production and tool retouching at the site) (Freeman and González Echegaray 2001).

Flakes were the most commonly produced lithic artifact in Urtiaga Level F
occupations. Plain flakes are the largest portion (20%) of the Level F assemblage; they
are followed by secondary decortication flakes (16%)(Table 1). An additional 18% of the
assemblage is comprised of fragmentary cortical and non-cortical flakes. There were only
nine primary decortication flakes (0.58%), indicating that early stage reduction occasionally occurred at the site despite its distance from raw material sources (Fig. 1). The majority of whole flakes (n=569) have flat platforms (68%), with lesser values for cortical platforms (14%), abrasive platforms (11%), and complex platforms (6%), which indicate earlier reduction stages, use of direct soft-hammer reduction techniques (two antler percussors were documented by Mugica (1983)), and platform shifting, respectively (Table 3). One artifact had a platform that was later retouched. 60% of the whole flakes had feathered terminations, indicating well-controlled flake propagation (Cotterell and Kamminga 1987). However, 23% of flakes had step terminations (due to insufficient force and/or crack arrest), 15% hinge terminations (from flake initiations directed into flattish core faces, resulting in insufficient energy in the propagation phase to remove the expanding developing flake), and 2% overshot terminations (caused by sharp cornered distal sections of nuclei) (see Cotterell and Kamminga 1987). Thus, in 40% of cases flake initiations were mislaid and/or force was misjudged by knappers, which could indicate that at least some flake manufacture resulted from inexperienced hands. Overall, flake reduction at the site was mid-late stage, indicating that primary raw materials exploitation occurred off-site, probably at sites closer to and/or at raw material source outcrops.

Collectively, blades are one fifth of the Urtiaga Level F lithic assemblage; more than half of these are non-cortical (Table 1). As is the case with flakes, many more blades are whole than fragmentary. Again, the lack of cortex among blades shows that primary reduction stages for these cores likely occurred elsewhere. Flat platforms were equally prevalent among blades as flakes, indicating similar initiations and propagations for both
artifact types. However, whole blades (n=211) do show greater instances of abrasive platforms (26%), indicating greater use of soft percussors in conjunction with pressure-flaking techniques to remove long, narrow products. Terminations area also overwhelmingly feathered; hinge, step, overshot, and modified terminations were collectively 26% among blades, far less than the same attributes among flakes. Bladelets (3.74% of the assemblage) were mostly fragmentary and non-cortical; those whole bladelets (n=23) in the assemblage show reduction attributes similar to those of blades, with overwhelmingly feathered terminations and evidence of soft-hammer reduction techniques (Table 3). Blade(let) reduction at Urtiaga cave was likely the result of a continuous reduction schema that gradually decreased in size, ultimately passing the blade/bladelet boundary (2cm length), shortly before cores were abandoned. These blade(let) reduction sequences appear better controlled and more standardized than their flake counterparts.

The most significant type of debris in the Urtiaga Level F assemblage are burin spalls, (n=102, or 6.58%). A quarter of these artifacts rejuvenated previously retouched portions of flakes, indicating that the burination technique was employed for the dual purpose of creating dihedral tools and repurposing previously retouched blanks, effectively conserving lithic raw materials via reuse. Other debris comprise small portions of the assemblage. Cortical and non-cortical chunks are collectively 2.77%. There are only three microburins (generally rare in Vasco-Cantabria), which were made using the notch and snap technique (see Inizan et al. 1992:69). Uni- and bi-directional crested blades constituted barely 1% of the assemblage, indicating that some blade reduction schemes began at Urtiaga cave. Platform renewal flakes are more abundant,
indicating mid-sequence core renewal wherein knappers shifted nuclei to exploit multiple surfaces. This also corresponds to instances of complex platforms among flake debitage, demonstrating that knappers used diverse means to remove flakes from cores in contrast to the rigorous structure and standardization of the blade(let) reduction schemes. Finally, 2% of the debris assemblage is splintered pieces (classified as both tools and debris), indicating that bipolar reduction techniques were also used in small amounts at the site in order to exploit small and/or refractory stones. Overall, the lithic debris assemblage from Urtiaga Level F is similar to others dating to c. 17,000 uncal. BP in the region (e.g. El Mirón) and demonstrates the importance of flake reduction in the Initial Magdalenian.

**Tools**

Barandiarán recovered 345 artifacts from Urtiaga Level F that had been modified into formal tools. A significant number of these were multi-use “Diverse” pieces, bringing the total tool (i.e., modified edges) count to 410 (Table 4). The summary presented here is based on the number of artifacts, while Table 4 presents the tools both as portions of the artifact assemblage and total tool count. “Diverse” tools are discussed in detail later in this section.

There were 32 endscrapers (9.3%) recovered from Urtiaga Level F; nucleiform endscrapers were the most abundant type. Together with atypical carinated and carinated varieties, the steep-angled scrapers comprise half of this tool type. Steep scrapers, particularly core scrapers, are a defining characteristic of the LCM (González Echegaray 1960). Burins comprise 10.7% of the Urtiaga Level F tool assemblage; most of these are angle on break burins, which are also typical of the LCM. There are only three burins on truncations. Transverse burins (n=7) were made on lateral retouch and notches; these
burin types are more common in Solutrean than LCM assemblages. Continuously retouched pieces, typically on single sides, are 11% of the assemblage, pointing to intensive flake/blade use and retouch at the site. “Archaic” pieces (collectively notches, denticulates, splintered pieces, sidescrapers, and raclettes) are the majority of the Urtiaga Level F assemblage (31%). Notches and denticulates were the most common “Archaic” pieces. There were only two pieces classifiable as raclettes. One, a true parallel flake with backing on three sides; the other, a preform made on a parallel flake with backing on one side and a small notch on the distal portion. The prevalence of these tools in the Urtiaga Level F assemblage—in single-purpose and multi-purpose “Diverse” varieties—affirms the hypotheses proposed by Straus (2013) and Aura et al. (2012) that “Archaic” tools were a major component of Initial Magdalenian toolkits.

There are ten composite tools (per de Sonneville-Bordes and Perrot’s definition) in the assemblage (2.9%). Seven of these tools included a burination (tool types 17 and 22) and eight a perforator (tool types 20, 21, 22). There are 23 perforators (6.7%), most are the atypical “stubby” variety. Truncations are also small in number—13 artifacts, 3.8% of the assemblage—most are oblique. Backed pieces (also 3.8%) are varied, and include typical and atypical Gravette points, a microgravette point, a few backed and partially backed blades, and a shouldered piece that was part of a composite “Diverse” tool. Bladelet tools were collectively 3.2% of the assemblage and included backed, truncated, and “Juyo” bladelets, though overall, backed pieces, whether blade or bladelet, were uncommon at Urtiaga. Finally, Aurignacian blades and Solutrean pieces are collectively 1% of the Urtiaga Level F assemblage. The Solutrean piece is a distal fragment of a unifacial point made on Treviño flint (Fig. 5 Sample E), broken via a snap
and dulled through use. Its exterior surface is cortical, with invasive retouch more prominent on the left side of the piece. This artifact is similar to Solutrean point fragments recovered from the Upper Solutrean level at nearby Arlanpe cave (Vizcaya), where Solutrean retouch also did not cover whole surfaces (Rios-Garaizar et al. 2013). Collectively, these minor tool types indicate mixture of Solutrean and Magdalenian elements in the weapons technology used by Initial Magdalenian occupants of Urtiaga cave.

After “Archaic” tools, “Diverse” pieces are the largest portion of the Urtiaga Level F tool assemblage (17.1%). There are a total of 124 individual tools distributed among the 59 artifacts that constitute this category. More broadly, “Diverse” pieces comprise nearly a third (30.2%) of the overall number of tools (n=410) recovered from Level F. The majority of “Diverse” tools are attributable to notches (n=23), denticulates (n=20), continuously retouched pieces (n=16), sidescrapers (n=12), splintered pieces (n=7), angle on break burins (n=7), and perforators (n=5). All other de Sonneville Bordes and Perrot types have four or fewer “Diverse” tools. “Diverse” modifications overwhelmingly echo tool types already prominent in the assemblage (“Archaic” and continuously retouched pieces) and/or incorporate burination(s), which, as indicated by the burin spalls, were often used to rejuvenate retouched tools. The prevalence of “Diverse” pieces in the Level F assemblage demonstrates that tool reuse and rejuvenation was an important aspect of Initial Magdalenian lithic technology at Urtiaga cave.

**Cores and Nucleiform Endscrapers**

Urtiaga Level F yielded 37 cores (Table 1). 31 of the 37 cores had at least one flake removal; four of the flake cores were discoidal. The core types reflect the
proportions of flake and blade debitage identified in the assemblage (Table 1). All of the cores were made on flints; most cores were microcrystalline or chalcedonic flysch flint (n=16), followed by Gaintxurizketa flysch flint (n=7), Urbasa (n=7), Chalosse (n=3), and unknown flints (n=4). 19 of the cores were tools, though only 14 of these were
nucleiform endscrapers with retouched and regularized platforms. Nucleiform endscrapers averaged 29mm length x 25mm width x 23mm thickness. Seven of the fourteen endscrapers were cortical; all cores made on Gaintxurizketa flysch flint (some 40km distant) had cortex. Most nucleiform endscrapers had one or two platforms (n=7 and 5, respectively), though there are two cores with three or four platforms. Single platform cores had a cumulative total of 30 removals, 18 of which showed hinge or step terminations (60% error rate) (Table 5). Hinge and step terminations are difficult to correct in lithic manufacture, particularly as core size diminishes under 3cm in each dimension: these features indicate core exhaustion (and correlate to the high percentages of hinge and step terminations among debitage summarized in Table 2). Those nucleiform endscrapers with the most platforms were also the most exhausted, with 75% error for a three-platform core and 88% for a four-platform core (Table 5). These pieces were likely transformed into endscrapers because they lost their utility as cores that could produce viable flakes, yet were not so disfigured by multi-platform exploitation as to be discoidal and/or globular, losing the functional profile typical of steep “goat’s hoof” endscrapers.

The remaining 23 cores averaged 27mm x 29mm x 25mm (L x W x Th), only slightly larger than the nucleiform endscrapers. All but four were cortical, and every core from the most proximal raw material outcrop, Gaintxurizketa flysch flint, had cortex. No clear distance-decay relationship is indicated by the other lithic raw materials; even cores from the far off Chalosse outcrop are cortical. Single platform cores had lower error rates than the equivalent nucleiform endscrapers (44% compared to 60%). However, multi-platform cores demonstrate high error rates. Overall, these cores indicate production
intensity: exploiting a nucleus from multiple directions to utilize as much of the raw material as possible. At Urtiaga, multi-platform cores are more common than single platform cores, which is likely a dual reflection of far away flint outcrops and settlement structure: the hunter-gatherers who occupied the cave may have conserved high-quality stones by working nuclei to utter exhaustion. Nucleiform endscrapers represent yet another reuse of raw material: these cores were repurposed into steep scrapers instead of being discarded. This practice is extremely common during the Lower Magdalenian in Vasco-Cantabria, with such intensity that these artifacts are a temporal marker for the period (González Echegaray 1960; Straus 1992, 2005; Straus et al. 2008; Utrilla 1981). The cores recovered in Urtiaga Level F indicate that this behavior was also practiced in the Initial Magdalenian.

**Raw Materials**

The majority of the Urtiaga Level F lithic assemblage was manufactured using flysch flint from outcrops ~100km to the NE of Urtiaga in southwest France (Fig. 1): chalcedonic (37.3%), microcrystalline (13.3%) and Bidache (2.6%) varieties (Table 6). The next most abundant flint identified is Urbasa (17.2%), which occurs in northern Spain some 50km SSE of Urtiaga. Gaintxurizketa flysch flint, though the toolstone that outcrops closest to Urtiaga, is only 10.3% of the assemblage. Two other distant flints contribute small portions of the Urtiaga F assemblage: Chalosse (5.5%) and Treviño (3%). In addition to these geographically known toolstones, small portions (each <3% of the total) of the Urtiaga assemblage are comprised of other flints, lutites, quartzites, and unidentified stones. The latter three kinds of materials are presumed local in origin, taken from riverbeds near the site to manufacture expedient tools.
Raw material use at Urtiaga cave demonstrates that Initial Magdalenian mobile toolkits balanced long-term toolstone usage with long distance mobility and settlement needs. Based on the assemblage’s composition, groups principally used two or three major materials for short-term activities—the lion’s share of the mobile toolkit upon a group’s arrival at Urtiaga and what was manufactured in quantity there—while safeguarding other materials for long-term transport and special uses. For example, artifacts made using Treviño indicate mid-stage reduction and a high proportion of burin spalls relative to other kinds of debris; this flint was clearly preferred for manufacturing dihedral tools (see Fig. 5. Sample L). This kind of mobile toolkit is in stark contrast to that identified at a nearby Upper/Final Solutrean site, Arlanpe (Vizcaya, 17,260+/−70 (Beta-261388) and 17,160+/−70 uncal. BP (Beta-261389)), where flint raw materials were also transported long distances, but were reserved exclusively for blade reduction (Rios-Garaizar et al. 2013). Flakes at Arlanpe, only a quarter of the assemblage, were manufactured on local lutites (Rios-Garaizar et al. 2013). Thus, changes in lithic technology that occurred during the Initial Magdalenian were not restricted to weapons production and a switch to predominantly flake-based manufacture: toolstone organization shifted—not just in what materials were used, but how they were used.

While hunter-gatherer use of Treviño and Urbasa remained constant throughout the Last Glacial, that the groups who occupied Urtiaga cave chose to manufacture nearly their entire toolkit (flakes, blade(lets), etc.) out of flints—some from very far away—indicates that they chose to depend on these materials (and pay the price for carrying them) rather than to rely on local, lower quality stones. Initial Magdalenian raw material provisioning was a complex balance between task-necessities and movement across changing
landscapes: depending on a single kind of material, flint, for (nearly) all aspects of lithic manufacture may have been a more adaptive in the face of environmental fluctuations than differentiating chaînes opératoires by raw material. However, long-distance flint transport would have created another problem: conserving high-quality toolstones for sufficient lengths of time so that costly procurement trips were minimized (see Gould 1980). It is possible that toolkit changes seen in the LCM—specifically those related to maintaining (i.e., Bleed 1986) assemblages, correspond to shifts in raw material management: increased occurrence of nucleiform endscrapers, which repurpose cores; increase in bladelet technology, which uses diminutive blanks; and prevalence of bipolar reduction techniques in areas with poorer local lithologies, among others (Fontes 2014a; González Echegaray 1960; Straus 1992, 2005; Straus et al. 2008).

Osseous Industry and Faunal Remains from Urtiaga Level F

Osseous Industry

The osseous industry from Urtiaga Level F is diverse. Mugica’s (1983) inventory summarized 56 pieces, including 28 antler sagaies, in addition to awls, needles, spatulas, perforated shells, percussors, and other worked bones (Fig. 6). The sagaies can be summarized as follows:

(a) one sagaie fragment with a double beveled base and biconvex cross section;

(b) ten sagaie fragments with varying circular cross sections: four circular, two sub-circular, two semi-circular, and two with double beveled bases;

(c) one double point with a circular cross section;

(d) one double beveled base fragment of a rectangular cross section sagaie;

(e) three centrally flattened sagaie fragments, two with double beveled bases;
(f) two triangular cross section sagaies;

(g) four quadrangular cross section sagaies: two fragments; one with a double bevel base; and one with tectiform engravings (pictured in Fig. 6 Sample A); and

(h) six fragments of sub-quadrangular cross section sagaies, one with so-called “hunting [tally] marks” on one side.

This projectile assemblage is remarkably variable; the pieces have nine different kinds of cross sections. All artifacts with intact proximal ends have double beveled bases, many with “anti-skid” marks. Similar sagaies have been identified in the Initial Magdalenian levels at El Mirón cave, some 70 km west of Urtiaga, in Levels 117-119.3, where artifacts have oval, circular, centrally flattened, oval-quadrangular, quadrangular, and semi-convex cross sections (Straus et al. 2014). Thus, Vasco-Cantabrian Initial Magdalenian technological variability was not restricted to lithic toolkits, but also a component in changing osseous industries, evidence that these hunter-gatherers experimented with different artifact forms—including stylistic and/or functional embellishments—as they designed new composite tool industries (Solutrean sagaies can also be diverse in cross section, though they are not abundant in assemblages) (Straus et al. 2014). Furthermore, the osseous industry from Urtiaga Level F demonstrates that the site was used for myriad activities during the Initial Magdalenian, including hunting, sewing, manufacturing shell ornaments, and other domestic activities, all in addition to lithic manufacture. Later LCM residential sites show similar characteristics in their osseous industries, although portable art items, especially engraved red deer scapulae, are more abundant in these more recent occupations (Barandiarán et al. 1985; Freeman and González Echegaray 2001; González Morales and Straus 2009).
Fig. 6. Selected osseous industry from Urtiaga Level F, including whole and fragmentary needles (items b and e); perforated *L. obtusata* (c) and *L. littorea* (d); and a double bevel base *sagaie* with tectiform engravings located within a lateral groove (a).
**Faunal Remains**

The most prevalent fauna recovered from Urtiaga Level F was red deer, which comprise 60.1% of the assemblage (based on the NISP, see Table 7; Altuna 1972). Ibex and chamois were the second most abundant species (all were adults); fox and roe deer (six adults and three juveniles) were less frequent (Table 7). There is also evidence of cold faunas, including reindeer and bison/aurochs. Finally, there are also small amounts of other large game species and carnivores: horse, cave bear, lion, and lynx; and small game: European moles and water voles, hares, weasels, and polecats (Altuna 1972). Initial Magdalenian hunter-gatherers complimented these terrestrial game species with limited shellfish gathering (Altuna and Mariezkurrena 2010). Limpets (most were *Patella vulgata*) were the most common comestible mollusc in Level F (38% of the malacofauna NISP). *L. obtusata* were also collected (38%), but these were used exclusively for use as ornaments (Fig. 6 Sample E; this is the only level in Urtiaga where *L. obtusata* were collected and perforated). *L. littorea* were also collected in small amounts; one of these was perforated (Fig. 6 Sample D). Overall, the diverse faunas recovered from Urtiaga Level F indicate a climate that was still cold—the Lascaux Interstadiual—but also warming, as forest species (deer) were hunted in quantity (Altuna 1972). The presence of montane, coastal, and valley/forest species indicate that Initial Magdalenian groups exploited a variety of environments located near Urtiaga cave. Additionally, their catch differed slightly depending on species: for example, adult mountain goats were obtained while adult and juvenile deer were acquired (Table 7). It is possible that hunter-gatherer groups who settled at Urtiaga were beginning to develop techniques well documented in later Magdalenian periods, including intensive environmental exploitation within site
catchment zones, animal mass slaughter, and utilizing landscape features (i.e., pursuing animals on migratory paths or as they traversed closed basins and/or narrow landscape features) (Freeman 1973; Kuntz and Costamango 2011; Marín Arroyo 2009; Straus 1992).

**Activity Areas in the Urtiaga Cave Vestibule**

Barandiarán and his team excavated an approximately 12m² area in the narrow Urtiaga vestibule, dividing the cave into eleven sectors (Barandiarán 1978a). The widest excavated portion of the vestibule is in sectors 7-9; a natural chimney is located in the cave ceiling between sectors 7 and 8 (Fig. 4). Faunal remains (analyzed by Altuna (1972)) were most densely concentrated to the north of the chimney, in sector 9; this cluster contained a third of the faunal assemblage. A second concentration of faunal remains was located in sectors 5 and 6, though generally, the fauna were more evenly distributed throughout the Urtiaga vestibule than were the lithic artifacts. Lithics were distinctly clustered in sectors 4 and 8, with slightly smaller densities in sectors 6 and 9 (Fig. 7). However, it is also important to note that due to early 20th century excavation techniques, the excavated sectors in Urtiaga cave are not equal in size; this could potentially bias density data toward larger sectors. On the other hand, the temporal density patterns indicate reuse of the same sectors throughout the Initial Magdalenian period (Fig. 8), which implies that the site’s occupants may have had spatial preferences. It is possible that the lithic and faunal concentrations were related to the vestibule dimensions, with one cluster in the outer vestibule before a constricted passage in sector 6, and a second at a wider inner vestibule section with a chimney that could have provided natural light and/or ventilation. Faunal remains were deposited to the north of lithic artifacts in both areas (e.g., lithics in sector 4, fauna in 5 and 6). In the outer
Fig. 7. Densities of lithic artifacts and faunal remains in the Urtiaga cave vestibule, by sector. Cave vestibule image was drawn following Barandiarán (1978a).

Fig. 8. Change in lithic artifact density as a percentage of the entire assemblage, based on depths identified in Urtiaga Level F. Depth listing is based on numbers represented in order from smallest to largest and is not to scale. Depth rectangles with incomplete borders represent those whose values also correspond to depths recorded in Level E.
vestibule, this could reflect cultural and/or natural formation processes: discard preferences associated with well-defined activity areas or depositional context due to the Level F occupation surface, which gradually sloped downward as it progressed inward (Fig. 4). While it is certainly possible that natural taphonomic processes moved faunal remains downslope in the outer vestibule, the duplicate depositional pattern in the rear sectors, where the occupational surface was nearly level, may be contextual evidence of patterned refuse disposal in an area where slope would not have been a significant taphonomic factor. Additionally, the inner vestibule sectors were the most densely occupied areas within Level F; here the layer is its at thickest. It is possible that this was a preferred activity area in Urtiaga cave due to its relatively spacious dimensions and chimney, which may have led to the large concentrations of lithic artifacts and faunal remains in these sectors.

While it is impossible to effectively correlate depths and spatiotemporally relate archaeological materials across Level F due to old excavation techniques and slope, each sector can be compared to the others in terms of its general density pattern (Fig. 8). The temporal lithic density data show relatively continuous occupations in sector 9, demonstrated by a long sequence with moderate concentrations of lithic artifacts. In contrast, the outer vestibule sectors indicate intermittent settlement of the cave with infrequent high-density clusters (Fig. 8). These varied spatiotemporal patterns could have been caused by differential settlement in Urtiaga cave (possibly different groups, seasons, and/or at different points in a settlement pattern), perhaps with long-term occupations based out of the inner vestibule and short-term visits focused in the outer area. Faunal remains do provide some additional evidence to this hypothesis: while remains of major
species (red deer, ibex, and chamois) were distributed throughout the entire excavated area, some species were only identified in the outer vestibule: European mole, hare, European water vole, European polecat, and stoat (Altuna 1972). While some of these species are classified as microfauna (e.g., European water vole) and are thus often considered to be non-anthropogenic “background” elements, Pleistocene human groups have also been known to procure small game like these when other resources were scarce (Jones 2007); for example, at Aitzbitarte IV (17,950+/−100 uncal. BP, GrN-5993), an Upper Solutrean site ~30km from Urtiaga, small moles and voles are the greatest portion of the faunal assemblage (Altuna 1972) and moles are very common in the Abri Dufaure on the border between the French Basque Country and Chalosse (Eastham 1995).

Consequently, the fact that the small animal remains were clustered within the same area of Urtiaga cave is contextual evidence that Initial Magdalenian foragers processed these animals at the site rather than that they were left by owl activity. Therefore, the Urtiaga outer vestibule testifies to some occupations wherein groups intensified (albeit in diminutive amounts, collectively 3.2% of the assemblage) a primarily large game-based diet with smaller species. While lithic density data support areas of intermittent and continuous occupation, it is also not possible to rule out that these areas were used concurrently, i.e., the vestibule rear was continuously occupied and an occasional second activity area was concentrated in the outer sectors. Overall, spatial and temporal deposition of lithic artifacts and faunal remains suggest patterned activity areas in Urtiaga cave that may have been similar to those that have been identified at another Initial Magdalenian site, El Mirón, where an extraordinarily large quantity of lithic tools were deposited in a 2m² area between a large block and the cave wall within that cave’s huge
vestibule (Straus et al. 2014). Defining spatial areas (and by proxy, investment in site structures), may have been as important to Initial Magdalenian hunter-gatherers as it was to those living during more recent Magdalenian periods in Spain, France, Switzerland and Germany (see examples in: Arambourou 1978; Audouze and Enloe 1997; Bosinski 2007; Fontes et al. 2013; Leesch et al. 2004; Straus 1987, 1992, 1995; 2013; Zubrow et al. 2010).

**Initial Magdalenian Mobility**

Urtiaga cave is an excellent location to explore Initial Magdalenian human mobility for two reasons: first, Barandiarán excavated and recorded contexts meticulously, and second, the vast majority of lithic artifacts could be attributed to geographically known outcrops. To assess the relationship between changing landscape use and lithic procurement, six samples were examined in detail, two each from sectors 4 (Units 270 (n=160) and 310 (n=81)), 6 (Units 325 (n=50) and 385 (n=85), and 8 (Units 400 (n=76) and 460 (n=100)) (hereafter abbreviated e.g., 6.325). Collectively, these samples comprise just over a third of the Urtiaga Level F assemblage and represent some of the richest depth units excavated in the level. Each sample is a heuristic unit and considered as a patterned occupational residue (contiguous for comparative utility, but not necessarily indicating a single event) of that sector of the Urtiaga vestibule. All units were examined individually; lower and upper units were not collectively considered as residues of single occupations spanning the length of the cave. Considering these units separately provided more detailed models of Initial Magdalenian behavioral patterns.

Several assumptions about Initial Magdalenian behavior were made to construct these models:
(a) raw materials identified in archaeological samples were considered proportionally equivalent (by weight) to their behavioral counterparts in mobile toolkits (i.e. if Treviño was 10% of an archaeological unit, it was also 10% of the toolkit when that occupation was made);

(b) provisioning events that occurred more recently were represented by higher portions (by weight) of raw material assemblages than those that occurred less recently. However, assuming that groups would have maximized weight efficiency in raw material transport by reducing the amount of cortex in the mobile toolkit and that early reduction stages occurred closest to outcrops (Beck et al. 2002; Elston 1990; Kuhn 1994), exceptions were made for raw materials in earlier reduction stages that indicated recent toolstone procurement. Reduction stages were standardized by comparison of debris types, size grades, and cortex/reduction (i.e., Table 2). Distance decay was assumed for the latter two variables, i.e., that flakes became progressively smaller as they were reduced and cortical portions waned. Primary cortex is considered a hallmark of early stage reduction; platform renewal, crested blades, and burin spalls, diagnostic of mid-stage reduction; and cores and bipolar pieces indicative of late stage reduction;

(c) Initial Magdalenian groups employed a foraging strategy (Binford 1980) that involved residential moves throughout a large territory (eastern Vasco-Cantabria is ~12,000 km$^2$) and acquired all of their raw materials through direct outcrop access. This assumption simplifies several dimensions of mobility behavior that are difficult to discern archaeologically, including the frequency of residential/logistical moves, who made them (individuals or groups), the possibility that materials were acquired via trade, and how groups managed other resources within their territory (Djindjian 2009, 2012; Gould 1980;
Additionally, this opposes the common Magdalenian territorial management model wherein groups focused their occupations at (typically coastal) residential bases and made logistical forays to specialized sites where they exploited different local catchment zones (González Morales and Straus 2009). While a collector-based system with logistical moves may be reasonable for Lower (and perhaps Initial) Magdalenian occupations in Cantabria province, valley-based coastal to montane site movement cannot explain the complexity of lithic sources used at Urtiaga and the large territorial area those toolstones represent (see also a summary by Rios-Garaizar et al. 2013 for the Upper Solutrean at Arlanpe cave in Vizcaya). While Initial Magdalenian groups could have traded for lithic raw materials (and some inter-group trade/interaction/diffusion is thought to have occurred during the period based on artifact similarities (Aura et al. 2012)), this would have been an exceptionally risky technological strategy to provision any large portion of a mobile toolkit, particularly in fluctuating Last Glacial environments (Altuna 1972; Jones et al. 2003). Additionally, Urtiaga Level F was intermittently occupied (at least in the outer vestibule), with lithic debris from mid-stage reduction and osseous industry indicating diverse activities; these attributes do not reflect a residential base, but a site occupied at a mid-point during a settlement round—certainly, proximal debitage fragments were removed from the site for later use and initial reduction stages occurred before groups arrived there. Further, were the site a base camp in a logistical system, it would have been cumbersome to schlepp any of the raw materials used at Urtiaga (the closest of which is 40km away) to the cave, particularly any of the flysch flints, the most common materials in the Level F assemblage, ~100km from their outcrops in southwest France;
(d) finally, all raw materials without geographically known outcrops were not considered.

In sum, the settlement analysis presented here combines patterns of lithic procurement, manufacture, use, and discard to ultimately model Initial Magdalenian mobility systems.

**Fig. 9.** Mobility models based on six samples from Urtiaga Level F. Order of residential moves is distinguished based on line color. White arrows represent the most recent (last) procurement events, progressing through several greys, finally to black lines, which indicate the toolstones procured first.

*Mobility Models*

The least abundant raw material in Unit 4.270 was Chalosse (2.4%)(Table 8). This outcrop was the earliest visited by Initial Magdalenian groups in this scenario (Fig. 9). Though not abundant, the debris at Urtiaga indicate mid-stage reduction, demonstrating that this high-quality material may have been conserved for still-later occupations of other sites in the group’s settlement system. After Chalosse, the next most abundant material in Unit 4.270 is Treviño (14.6%), which was also in mid-stage reduction. Also mid-stage, Gaintxurizketa flysch flint (16.8%) is slightly more prevalent.
These materials are followed by chalcedonic and microcrystalline flysch flints (together 35.5%); these debris indicate early to mid stage reduction. Debris from Urbasa (25.5%) indicate all stages of a lithic reduction sequence ending with a bipolar piece; with a whole reduction sequence present, Urbasa was the source most recently visited in this mobility model.

In Unit 4.310, Treviño (mid-stage, 3.5%) is the least abundant raw material, followed by Chalosse (mid-stage, 7.4%). From Chalosse, this model hypothesizes group movement along the coast to Gaintxurizketa flysch flint outcrops (mid-stage, 8.5%) before visiting Urbasa (late stage, with flake and bipolar reduction techniques, 21.1%). Finally, chalcedonic and microcrystalline flysch flint debris indicate recent procurement of these materials. Chalcedonic flysch flint (29.4%) debris demonstrate an entire reduction sequence, beginning with blade reduction through mixed flute/bladelet production. Microcrystalline flysch flint (19.4%) was reduced using bipolar techniques. This model suggests that groups traversed a very large territory while also balancing long- and short-term raw material needs, conserving small amounts of materials like Treviño and Chalosse and utilizing flysch flints in greater quantity. However, it is important to note that Unit 4.310 has a small sample size; these results should be observed with caution.

While the Gaintxurizketa flysch flint outcrop would seem a logical location to procure toolstone in quantity before visiting Urtiaga cave, the model generated using debris from Unit 6.325, another unit with a small sample size, shows this material as a minor (4%) contributor to the mobile toolkit. Unlike the models from Units 4.270 and 4.310, where different reduction stages were discernable, all toolstones identified in Unit
6.325 were mid-stage; the order of material access is based solely on toolstone abundance. Treviño was the next most prevalent material (10.7%), followed by Chalosse (13.5%), Urbasa (27.9%), and flysch flints (chalcedonic, 28.7% and microcrystalline, 13.2%). Unlike the other settlement models, which have circular/spiral patterns across the eastern Vasco-Cantabrian landscape, the Unit 6.325 model is a regional zigzag of large-scale territorial moves. Such movements could have been the result of unstable, fluctuating local environments and/or limited available resources, making smaller scale moves unrealistic.

Treviño is the least abundant material in Unit 6.385 (3.7%, mid-stage), followed by Chalosse (5.3%, late stage), then Gaintxurizketa flysch (mid-late stage, 18%). All three French flysch flints are present in this sample: chalcedonic (mid-late stage, 22.6%), microcrystalline (mid-stage, 9.2%), and Bidache (mid-stage, 6.5%). Finally, Urbasa is the most abundant mid-stage toolstone (19.8%), indicating that it was the outcrop most recently visited by foragers in this model. This scenario, another model relying on a small sample size, shows greater mobility within southwest France between the area bounded by the Gaintxurizketa, Chalosse, and flysch flint outcrops. This model contrasts the zigzag settlement indicated shown by Unit 6.325; this difference may be attributable to environmental and/or territorial shifts occurring within the Initial Magdalenian period.

In Unit 8.400, over a quarter of the raw materials (27.3%) are not attributable to a geographically known outcrop; all identifiable flints are in lesser abundance than in previous models. Chalosse (mid-stage, 1.1%) is the least abundant material, then, Treviño and Urbasa (mid-stage, 7.1 and 7.9% respectively). While chalcedonic flysch flint is prevalent (37.5%), it is mid-late stage. Other flysche flints (Bidache and microcrystalline,
both mid-stage) are only 4% each. Gaintxurizketa flysch flint was the most recently procured toolstone (mid-stage, 11.4%) before groups arrived at Urtiaga; though it is less abundant than the chalcedonic flysch flint, it is not as reduced. The Unit 8.400 model shows a large circular territory extending through the ~12,000 km$^2$ eastern Cantabrian zone, however, both the small sample size and large percentage of unidentifiable toolstones in this sample make this hypothesis a tenuous one.

Finally, the Unit 8.460 assemblage has very little Chalosse (mid-stage, 3.5%) and equal amounts of Treviño and Urbasa (mid-stage, 6.4%) (Treviño is shown as accessed first in Fig. 9 following precedent set by the other scenarios, but really either outcrop could have been). There is also a small amount of Gaintxurizketa flysch flint (mid-stage, 7.5%) in this sample. The majority of the raw materials in Unit 8.460 are chalcedonic (48.6%, mid-stage) and microcrystalline (20.4%, mid-late stage) flysch flints. This unit suggests that French flysch flint outcrops (a combined 69% of the Unit 8.460 toolstone assemblage) were important locations within Initial Magdalenian settlement systems; these flints may have been a major resource for hunter-gatherer groups who lived in eastern Vasco-Cantabria.

Summary

While heuristic, these six mobility models show that Initial Magdalenian land use was dynamic; no two scenarios are the same. These models provide several scales of behavioral data, including flint preferences, toolkit management, and landscape use. Five major conclusions can be drawn:

(a) Despite its proximity to Urtiaga, Gaintxurizketa flysch flint was the most recently accessed toolstone in only one model (Unit 8.400). That this material was not
preferred is perhaps due to occasional large inclusions found in it, which would have made it a less reliable material than the other flysch and non-flysch flints discussed here, particularly for blade(let) reduction. Initial Magdalenian hunter-gatherers may have considered raw material quality as they formed their mobile toolkits;

(b) Initial Magdalenian mobile toolkits were likely designed to provision long-term raw material needs. In every settlement model, Chalosse and Treviño debris comprise small portions of mobile toolkits that are still in mid-stage lithic reduction: assuming the models accurately reflect human behavior, these stones may have been accessed first, yet conserved as groups continued to traverse eastern Vasco-Cantabria. This kind of raw material management would have been necessary (and an asset) to lithic economies with mobile flint foundations and limited local (lower quality) toolstone provisioning;

(c) In addition to long-term raw material stockpiling within mobile toolkits, Initial Magdalenian groups also may have procured materials for short-term use: Urbasa and French flysch flint. In all but one settlement model, foragers visited Urtiaga following raw material acquisition at one (or both) of these sources. These samples show that Initial Magdalenian toolkits were probably multi-purpose, balancing long- and short-term lithic reduction needs and movement within the large eastern Vasco-Cantabria territory. Thus, Initial Magdalenian groups would have had to plan their moves in advance (perhaps seasonally) in order to adequately provision their mobile toolkits;

(d) While mobile toolkit composition shifted throughout the Initial Magdalenian (or at least in each detailed sample considered here), the tools deposited at Urtiaga cave did not change (Table 9). Though the samples are small, they indicate that the same kinds
of tools were deposited at the cave throughout the period as shown in the cumulative tool summary: notches, denticulates, continuously retouched pieces, and burins are most prevalent in each unit. Despite raw material fluctuations, the activities that occurred in Urtiaga cave appear to have remained consistent during the Initial Magdalenian;

(e) Finally, these models propose that Initial Magdalenian groups diversified their mobility following two general patterns: either 1) concentrating settlement in small areas within the large eastern Vasco-Cantabrian territory (e.g., Units 4.310 or 4.270); or 2) traversing (nearly) the entire landscape (e.g., Units 6.325 or 8.400). Collectively, the six samples suggest Initial Magdalenian territorial shifting that was likely related to local (perhaps seasonal) environmental patchworks, resource availability, and/or cultural boundaries. Modifying mobility strategies, and especially employing long-term mobility systems, is one strategy hunter-gatherers employ to respond to subsistence stress (Hames 1987; Kelly 1992). During the Initial Magdalenian, residents of Vasco-Cantabria were in flux: environmentally, territorially, and technologically as they sought the most effective organizational solutions to a challenging subsistence context. It is possible that by the LCM, when technology and environment stabilized (Aura et al. 2012), that Vasco-Cantabrian groups were able to restructure their territories into the valley-based framework proposed by Straus (1986) and González Morales and Straus (2009) and form a distinct regional band identifiable by unique portable art objects: engraved scapulae.

The Initial Magdalenian Mosaic

The multifaceted analysis presented here suggests Initial Magdalenian behavioral complexity beyond the artifact traits routinely discussed by prehistorians as diagnostic features of the Solutrean-Magdalenian transition: flake production, increasing backed
bladelets and corresponding decrease in Solutrean points, an “Archaic” toolkit, occasional raclettes, increasing prevalence of osseous sagaie industry, and local raw material use (Aura et al. 2012; Straus 2013; Straus et al. 2014). Materials from Urtiaga Level F conform to these traits (except in the case of local raw material use), but also indicate that Initial Magdalenian hunter-gatherers may have: exploited comestible resources that lived in environmental zones near their habitation sites; spatially defined activity areas within caves; reused sites as part of patterned settlement systems; strategically managed their mobile lithic toolkits to meet long/short term technological goals, both in toolstone provisioning and tool production (blank selection and subsequent transport off-site); shifted their mobility and lithic procurement strategies within a large eastern Cantabrian territory; and employed myriad strategies to maintain their lithic toolkits in order to effectively exploit shifting environments in the region following the Last Glacial Maximum. This synthesis explores whether or not these behaviors were unique to groups who used Urtiaga cave or are features that could distinguish Initial Magdalenian adaptations from the Solutrean and Lower Magdalenian periods by focusing on the trend that defines this transition: a shift from reliable to maintainable technology.

Maintainable technology is designed to be easily repaired and retooled, extending artifact use lives (Bleed 1986). This kind of technological system allows groups to efficiently exploit variable, fluctuating, and/or unpredictable environments (Pereira and Benedetti 2013). Since maintainability is an organizational characteristic, its features can be traced within artifact assemblages. In lithic reduction, toolkit maintenance is demonstrated by burin rejuvenation, bladelet production, bipolar reduction, used debitage, multi-platform cores, nucleiform endscrapers, and composite tools (see Supplement B).
Additionally, four other traits testify to maintainable organizational systems: diverse *sagaies* in toolkits; blank selection and transport; consistent, redundant site activities; and flint dependence (see further explanation in Supplement B). In order to assess how extensively Initial Magdalenian groups maintained their assemblages, each of these 11 attributes was evaluated using published results from analyses made at four other Initial Magdalenian/Upper Solutrean sites in Vasco-Cantabria: La Riera Level 17 (Asturias, 16,900+/−200 (GaK-6445) and 17,070+/−230 (GaK-6444) uncal. BP); El Rascaño Level 5 (Cantabria, 16,430+/−130 uncal. BP (B.M. 1455)); El Mirón Levels 117-119.3 (Cantabria, Level 117 17,050+/−60 uncal BP, GX-25857); and Arlanpe Level 2 (Vizcaya) (González Echegaray and Barandiarán 1981; Rios Garaizar et al. 2013; Straus and Clark 1986; Straus et al. 2014); results are summarized in Table 10.

While four maintenance characteristics discussed here (burin rejuvenation, used debitage, multiplatform cores, and blank selection/transport) cannot be effectively evaluated because they lack reference in the published data, the seven characteristics compared in Table 10 demonstrate that Initial Magdalenian hunter-gatherers maintained their lithic assemblages. Some lithic toolkits were maintained during manufacture (La Riera and El Mirón), showing high proportions of bladelets in debris assemblages: 37% at El Mirón and 23% at La Riera, with moderate amounts of nucleiform endscrapers (c.20% of cores) and very few “Diverse”/composite tools at each site. In contrast, the Urtiaga, El Rascaño, and Arlanpe assemblages indicate use-related maintenance. “Diverse”/composite tools at Urtiaga (20%) and Arlanpe (17%) are significantly higher than at El Mirón and La Riera; El Rascaño is a middle ground at 7%. Cores were repurposed into nucleiform endscrapers at rates of 38% and 42% at Urtiaga and El
Rascaño, respectively. Arlanpe had no nucleiform endscrapers, but a higher percentage of blade(let) production (15%) than the other two sites. Bipolar reduction was under 2% at all Initial Magdalenian sites (in later LCM contexts, they can be as much as a sixth of an assemblage (Fontes 2014a)). Finally, osseous industry and site activities offered no significant trends: diverse *sagaies* were absent from the Upper Solutrean sites (Arlanpe and La Riera) and site activities were (spatio)temporally consistent when this was evaluated. Flint dependence in assemblages correlated to site proximity to high-quality lithic raw materials; the greatest concentrations were in eastern Vasco-Cantabria, where Urtiaga has an almost entirely flint-based assemblage, decreasing westwardly toward Asturias, where flint is a small portion of the La Riera assemblage.

All five assemblages evaluated here indicate aspects of toolkit maintenance that are prominent characteristics of later LCM assemblages (González Echegaray 1960; Utrilla 1981). However, unlike LCM assemblages, Initial Magdalenian toolkits reflect selective use of maintenance strategies. That an assemblage indicates particular maintenance strategies may not have related to a single approach (e.g., groups choosing to maintain during manufacture or use), but instead, a behavioral continuum. Since lithic reduction follows predictable patterns, maintenance behaviors should correlate to specific moments in the lithic reduction sequence where each strategy would prove most effective at conserving raw material and prolonging toolkit use-life (Fig. 10). How maintenance strategies were used likely related to the conditions of mobile toolkits upon arrival at a location, occupation span, site position within a settlement pattern, and raw material availability (both local and distant) (Bleed 1986). For example, the La Riera and El Mirón assemblages both indicate later stages of lithic reduction based on their lithic
Fig. 10. Maintenance continuum. Maintenance behaviors are listed relative to lithic reduction stages (earlier through later). Beneath the continuum, lines indicate which maintenance behaviors occurred at Initial Magdalenian sites.

debris—lots of plain flakes and bladelets—with corresponding late stage maintenance behavior (Fig. 10; Straus and Clark 1986; Straus et al. 2014). In contrast, the Urtiaga Level F lithic assemblage testifies to mid-stage reduction and earlier stages of toolkit maintenance: debitage use, blank selection, “Diverse”/composite tools, and burin rejuvenation (though there are high percentages of multi-platform cores and nucleiform endscrapers, these are comparatively few artifacts relative to the number of used and “Diverse” pieces (see Tables 1, 4 and 5)). Thus, maintenance strategies suggest that specific lithic reduction stages occurred at different locations, reinforcing the aforementioned hypothesis that Vasco-Cantabrian Initial Magdalenian groups were highly mobile. Were these groups occupying sites for long intervals, i.e., seasonally, a greater range of maintenance behavior would be evident in each lithic assemblage. For example, at the LCM residential base in El Mirón, all of these maintenance strategies were commonplace, the result of complex occupations that required a broad range of lithic reduction/products (Fontes 2014a, 2014b; Fontes et al. 2015; González Morales and Straus 2009; Straus et al. 2008). In contrast, at the LCM hunting stand at El Rascaño,
maintenance strategies indicate late-stage reduction with high amounts of nucleiform endscrapers and bipolar pieces, consistent with an occupation that was limited in its scope and logistically provisioned (Fontes 2014b; González Echegaray and Barandiarán 1981). Thus, the maintenance strategies and reduction characteristics that indicate residential mobility patterns in the Initial Magdalenian also correspond to the logistical mobility systems hypothesized for the LCM and explain some of the known variation in LCM assemblages (González Echegaray 1960; González Morales and Straus 2009; Straus 1992, 2013; Utrilla 1981). In sum, maintenance strategies are not only important in terms of understanding the Solutrean-Magdalenian transition from a technological standpoint, but in reconstructing the Initial Magdalenian mosaic: how groups utilized the Vasco-Cantabrian landscape and importantly, how their strategies gradually shifted into well-defined LCM patterns (González Echegaray 1960; González Morales and Straus 2009; Straus 1992, 2005, 2013; Straus et al. 2008; Utrilla 1981).

**Urtiaga Cave and the Solutrean-Magdalenian Transition**

This analysis of the Urtiaga Level F assemblage advances archaeological understanding of the Solutrean-Magdalenian transition in several ways. First, the lithic assemblage, which includes mixed Solutrean and Magdalenian artifacts and whose toolstone proveniences indicate a settlement pattern that did not extend beyond Landes, France, provides further evidence of *in situ* cultural change during the c.18-16,000 uncal. BP interval in Vasco-Cantabrian Spain. These assemblage features reinforce the hypothesis that the Initial Magdalenian was a regional archaeological culture only peripherally related to the French Badegoulian, which developed c.1000 years earlier (Corchón 1981, 1984; Straus 1983, 2000, 2013, 2015; Straus et al. 2014; de la Rasilla and
Straus 2006). Second, this analysis has shown that though the Initial Magdalenian may not be traceable by a single artifact type (unlike the Badegoulian, with its diagnostic raclettes), it can be summarized based on its economic characteristics: flake reduction; a mixed toolkit indicative of gradual replacement of one armature system (Solutrean points) with another (sagaies and microblade insets); assemblage maintenance via burin rejuvenation, bipolar reduction, bladelet production, composite tools, etc.; and evidence that groups managed toolkits to adapt to long- and short-term needs within a mobile economy. These economic characteristics are neither Badegoulian nor Solutrean, but are unique to the Initial Magdalenian and could have related to environmental and/or cultural factors that influenced regional technological solutions (e.g., limited social networks during the Solutrean-Magdalenian transition or local resource shifts in the Last Glacial Vasco-Cantabrian environmental patchwork). Thus, Urtiaga cave is an important reference site that archaeologists can compare with other assemblages from the Solutrean-Magdalenian interval in order to better understand the “desolutreanization” processes in Vasco-Cantabria.

The Urtiaga cave case study serves as a metaphor for how archaeologists can investigate regional cultural trajectories in the Upper Paleolithic: by synthesizing site- and landscape-level datasets (see also Banks et al. 2009, 2011). Through multi-faceted studies, archaeologists can explore inter-group interactions, human-environmental dynamics, and large scale technological and cultural change. These issues are at the heart of the Solutrean-Magdalenian transition, but also broader questions in Upper Paleolithic archaeology. Throughout the Upper Paleolithic, there are traces of regional histories having a significant influence on broader cultural trajectories (e.g. artistic or
technological diffusion) (González Morales and Straus 2009; Otte 2012). The Badegoulian and Initial Magdalenian may have been two differing regional solutions to a broader “desolutreanization” problem—both archaeological cultures diverge, albeit in different ways, from the Solutrean, whose technological (and cultural?) behaviors were no longer adaptive. Whether the impetus for the transitions were climatic, environmental, socio-cultural, or some combination therein, the nature of Badegoulian and Initial Magdalenian adaptations was likely influenced by the cultural-historical trajectories established at the end of the Solutrean period in these respective regions, which in turn would have informed the kinds of cultural processes—technologies, territories, inter-group connections—that would succeed.

**Conclusions**

This paper synthesized results from analyses of Urtiaga Level F lithic industry, osseous industry (Mugica 1983), and faunal remains (Altuna 1972), and presented an intra-site spatial comparison and a series of mobility models as part of a multi-faceted methodological procedure. Additionally, assemblages from Urtiaga Level F were compared with those from four other sites in the Vasco-Cantabrian region that were occupied at c. 17,000 uncal. years BP to assess an important feature of the Solutrean-Magdalenian transition: toolkit maintenance. Together, these analyses provide a holistic behavioral perspective of Initial Magdalenian hunter-gatherer adaptations and indicate that maintenance was a key component of technological organization during this period. Further, these analyses suggest that there was no typical Initial Magdalenian assemblage, just as there were no typical Solutrean or LCM assemblages: technological and associated mobility strategies likely varied to confront local geographic circumstances, including
topography, lithology, and ecology (Straus 1992, 2012; Straus and Clark 1986; Straus et al. 2014). That this technological variation persists in the Vasco-Cantabria throughout the Upper Paleolithic is itself evidence of *in situ* regional adaptations that were probably related to this unique, highly variable, geographically circumscribed environmental zone whose resources differed fundamentally from those in France and therefore would have required different kinds of technological and settlement flexibility than those found in transitional Badegoulian industries (see Banks et al. 2011; Ducasse 2012; Ducasse and Langlais 2007; but also Bosselin and Djindian 1999). This interpretation is analogous to differences in faunal exploitation and settlement strategies in the two regions: while French Magdalenian groups in areas like the Paris Basin were residentially mobile serial specialists, Vasco-Cantabrian groups had more broad spectrum diets, incorporating significant amounts of fish and shellfish into their diets long before their French counterparts (Altuna 1972; Audouze 2006, 2007; Freeman and González Echegaray 2001; Barandiarán et al. 1985; Straus 1992, 2005). Regional cultural “expressions” were an enduring feature in the western European Upper Paleolithic, even during technological transitions (Aura et al. 2012).

Urtiaga Level F, together with the records of four other c.17,000 uncal. BP occupations, suggests an Initial Magdalenian mosaic, largely continuous with its preceding Solutrean and succeeding LCM, that was created by highly mobile hunter-gatherers who may have shifted their movements within large territories, creating patterned large- and small-scale settlement systems where caves like Urtiaga were likely reused for similar purposes through time. These groups may have spatially defined their sites, reusing activity areas and exploiting faunas that lived locally. Their lithic
technology may have been strategically managed, balanced for long- and short-term needs, with blanks selected during reduction so that non-specialists could maintain the toolkit when the need arose. Maintenance strategies paralleled reduction sequences, with separate *chaînes opératoires* for flakes and blade(let)s. These groups made “archaic” tools a technological focus, and developed bladelet armatures alongside a diverse *sagaie* industry. They probably adjusted their strategies to meet the demands of local, poorer lithologies in western Vasco-Cantabria. Over the course of some 2000 years, these groups would establish LCM behavioral patterns—smaller territories, intensive site-catchment zone exploitation, wild harvesting, aggregation, extensive use of bipolar reduction, and unique portable art—traces of which are evident in the five Initial Magdalenian assemblages examined here. Those groups who visited Urtiaga during the Initial Magdalenian were planting their cultural roots—technologies, networks, traditions—grounded in their “Solutrean” history, gradually branching into a “Magdalenian” future that would continue to grow across the European landscape until the end of the Last Glacial.

This case study from the Solutrean-Magdalenian transition in northern Spain, Urtiaga cave, has described and operationalized some kinds of methodological procedures that archaeologists can use to effectively incorporate artifacts recovered from early 20th century archaeological excavations into modern interpretive frameworks. The significant results yielded by this study convey how important it is that archaeologists consider these data sources (albeit within recording limitations) as they frame their current research. As this study has shown, archaeologists can use data from these sources to examine prehistoric continuity and change between cultural-historical units.
Incorporating materials recovered using different procedures, where applicable, has the potential to not only increase anthropological understanding of prehistoric lifeways, but can ensure that important elements of the prehistoric archaeological record do not become lost to history simply because they were obtained using excavation methods that may not meet today’s standards. Furthermore, studies of this type become increasingly important as archaeological methodologies become more advanced each year. After all, current archaeological methods will eventually also be outdated. Old stones serve as a humble reminder of a responsibility to document archaeological research methods and data as accurately as possible as the discipline moves forward.

Acknowledgements

I would like to thank Koro Mariezkurrena and Jesús Altuna for the opportunity to study the Urtiaga collections at the Centro de Custodia de los Materiales Arqueológicos y Paleontológicos de Gipuzkoa in San Sebastián, Spain, and for their assistance during my ten weeks of research there. The National Science Foundation Doctoral Dissertation Improvement Grant #1318485, the University of New Mexico Latin American and Iberian Institute Ph.D. fellowship, and an American Association of University Women American Dissertation Fellowship funded this research. Lawrence Guy Straus has provided unwavering support during my dissertation research. Both he and Emily Lena Jones provided helpful comments and corrections on earlier drafts of this manuscript.
Table 1. Urtiaga F Debris Summary and Breakdown by Major Flint Types

.Raw material types are abbreviated as follows: Bidache (BID), Chalosse (CHAL), Chaledonic flysch (CHF), Gaintxurizketa flysch (GXF), Microcrystalline flysch (MF), Treviso (TR), Urbasa (URB), all other toolstones (OT), and microdebitage (MD). Assemblage portion is based on the total number of each debris type.

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<th>CHF</th>
<th>GXF</th>
<th>MF</th>
<th>TR</th>
<th>URB</th>
<th>OT</th>
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Table 2. Lithic Attribute Summary Urtiaga Level F.
Portions were classified as: \( W = \) Whole, \( P = \) Proximal, \( M = \) Mesial, \( D = \) Distal, \( L = \) Longitudinal, and \( I = \) Indeterminable. Cortex/Reduction summarizes the relationship between cortex and dorsal removal scars on whole debitage following the attributes described in the text (e.g., \( C1D3 \) refers to pieces with \(<\!1/3 \) cortical surface and three or more dorsal removal scars).

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<th>Portion</th>
<th>Count</th>
<th>Cortex/Reduction</th>
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Table 3. Urtiaga Level F Whole Debitage Platforms and Terminations
Platforms are abbreviated as follows: \( A = \) Abrasive, \( C = \) Cortical, \( CX = \) Complex, \( F = \) Flat, and \( R = \) Retouched. Abbreviations for terminations are: \( F = \) Feathered, \( H = \) Hinge, \( M = \) Modified (partially retouched or burinated), \( O = \) Overshot, and \( S = \) Step.

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<th>Bladelets ((n=23))</th>
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<tr>
<td>H</td>
<td>88</td>
<td>H</td>
</tr>
<tr>
<td>M</td>
<td>16</td>
<td>M</td>
</tr>
<tr>
<td>O</td>
<td>12</td>
<td>O</td>
</tr>
<tr>
<td>S</td>
<td>129</td>
<td>S</td>
</tr>
</tbody>
</table>
Table 4. Lithic tools from Urtiaga Level F.
Tools were classified using the de Sonneville Bordes and Perrot (1954, 1955, 1956a, 1956b) Upper Paleolithic tool typology. Parenthetical values represent the distribution of tools on pieces classified as “Diverse”. Totals are summarized for each tool category, with the parenthetical value as the sum of the “Diverse” tools distributed among the category. Two portions were calculated: (1) assemblage portion: the percent contribution of each tool category to the assemblage (n=345 artifacts); and (2) tool portion: the percent contribution of each tool category to the total number of tools identified at the site (n=410 with the addition of 124 tools classified as “Diverse”).

<table>
<thead>
<tr>
<th>Tool Type</th>
<th>Count</th>
<th>Tool Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Endscrapers</strong></td>
<td></td>
<td><strong>Composite Tools</strong></td>
<td></td>
</tr>
<tr>
<td>Simple endscraper</td>
<td>3 (1)</td>
<td>Endscraper-burin</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Atypical endscraper</td>
<td>3</td>
<td>Perforator-truncated piece</td>
<td>1</td>
</tr>
<tr>
<td>Double endscraper</td>
<td>1</td>
<td>Perforator-endscraper</td>
<td>2</td>
</tr>
<tr>
<td>Endscraper on retouched flake/blade</td>
<td>5</td>
<td>Perforator-burin</td>
<td>5</td>
</tr>
<tr>
<td>Endscraper on flake</td>
<td>1</td>
<td><strong>Totals (#)</strong></td>
<td>10 (1)</td>
</tr>
<tr>
<td>Carinated endscraper</td>
<td>2</td>
<td>Assemblage portion (%)</td>
<td>2.9</td>
</tr>
<tr>
<td>Atypical carinated endscraper</td>
<td>3 (1)</td>
<td>Tool portion (%)</td>
<td>2.7</td>
</tr>
<tr>
<td>Thick nosed endscraper</td>
<td>1</td>
<td><strong>Perforators</strong></td>
<td></td>
</tr>
<tr>
<td>Flat nosed/shouldered endscraper</td>
<td>(1)</td>
<td>Perforator</td>
<td>4 (1)</td>
</tr>
<tr>
<td>Nucleiform endscraper</td>
<td>13 (2)</td>
<td>Atypical perforator</td>
<td>16 (5)</td>
</tr>
<tr>
<td><strong>Totals (#)</strong></td>
<td>32 (5)</td>
<td>Multiple perforator</td>
<td>1 (2)</td>
</tr>
<tr>
<td><strong>Assemblage portion (%)</strong></td>
<td>9.3</td>
<td>Microperforator</td>
<td>2 (2)</td>
</tr>
<tr>
<td><strong>Tool portion (%)</strong></td>
<td>9</td>
<td><strong>Backed Pieces</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Burins</strong></td>
<td></td>
<td>Gravette point</td>
<td>4</td>
</tr>
<tr>
<td>Straight dihedral burin</td>
<td>2 (3)</td>
<td>Atypical Gravette point</td>
<td>1</td>
</tr>
<tr>
<td>Slanted dihedral burin</td>
<td>3 (3)</td>
<td>Microgravette</td>
<td>1</td>
</tr>
<tr>
<td>Angle dihedral burin</td>
<td>(1)</td>
<td>Shouldered piece</td>
<td>(1)</td>
</tr>
<tr>
<td>Angle on break burin</td>
<td>15 (7)</td>
<td>Completely backed blade</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Multiple dihedral burin</td>
<td>5</td>
<td>Partially backed blade</td>
<td>5</td>
</tr>
<tr>
<td>Burin on oblique retouched truncation</td>
<td>2</td>
<td><strong>Totals (#)</strong></td>
<td>13 (5)</td>
</tr>
<tr>
<td>Burin on concave retouched truncation</td>
<td>(1)</td>
<td>Assemblage portion (%)</td>
<td>3.8</td>
</tr>
<tr>
<td>Transverse burin on lateral retouch</td>
<td>6</td>
<td>Tool portion (%)</td>
<td>4.4</td>
</tr>
<tr>
<td>Transverse burin on notch</td>
<td>1 (3)</td>
<td><strong>Truncated Pieces</strong></td>
<td></td>
</tr>
<tr>
<td>Multiple burin on retouched truncation</td>
<td>1</td>
<td>Straight truncated piece</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Multiple mixed burin</td>
<td>2</td>
<td>Oblique truncated piece</td>
<td>7 (1)</td>
</tr>
<tr>
<td>Flat face burin</td>
<td>(2)</td>
<td>Concave truncated piece</td>
<td>2</td>
</tr>
<tr>
<td><strong>Totals (#)</strong></td>
<td>37 (20)</td>
<td>Convex truncated piece</td>
<td>1</td>
</tr>
<tr>
<td><strong>Assemblage portion (%)</strong></td>
<td>10.7</td>
<td>Bitruncated piece</td>
<td>1</td>
</tr>
<tr>
<td><strong>Tool portion (%)</strong></td>
<td>13.9</td>
<td><strong>“Archaic” Pieces</strong></td>
<td></td>
</tr>
<tr>
<td><strong>“Archaic” Pieces</strong></td>
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<td><strong>Assemblage portion (%)</strong></td>
<td>3.8</td>
</tr>
<tr>
<td>Notch</td>
<td>50 (23)</td>
<td>Tool portion (%)</td>
<td>3.7</td>
</tr>
<tr>
<td>Denticulate</td>
<td>28 (20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Splintered piece</td>
<td>26 (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sidescraper</td>
<td>2 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raclette</td>
<td>1 (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>107 (63)</td>
<td><strong>Assemblage portion (%)</strong></td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Tool portion (%)</strong></td>
<td>41.5</td>
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<table>
<thead>
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<th>Tool Type</th>
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<th>Count</th>
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<tbody>
<tr>
<td><strong>Continuously Retouched Pieces</strong></td>
<td></td>
<td><strong>Bladelet Tools</strong></td>
<td></td>
</tr>
<tr>
<td>Continuously retouched piece 1</td>
<td>35 (16)</td>
<td>Backed bladelet</td>
<td>6</td>
</tr>
<tr>
<td>Continuously retouched piece 2</td>
<td>3</td>
<td>Truncated backed bladelet</td>
<td>2</td>
</tr>
<tr>
<td><strong>Totals (#)</strong></td>
<td><strong>38 (16)</strong></td>
<td>Retouched bladelet</td>
<td>3</td>
</tr>
<tr>
<td>Assemblage portion (%)</td>
<td>11</td>
<td><strong>Total (#)</strong></td>
<td><strong>11</strong></td>
</tr>
<tr>
<td>Tool portion (%)</td>
<td>13.2</td>
<td>Assemblage portion (%)</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tool portion (%)</td>
<td>2.7</td>
</tr>
<tr>
<td><strong>Diverse</strong></td>
<td></td>
<td><strong>Other Tools</strong></td>
<td></td>
</tr>
<tr>
<td>Diverse</td>
<td>59</td>
<td>Aurignacian blade</td>
<td>1 (2)</td>
</tr>
<tr>
<td><strong>Total (#)</strong></td>
<td><strong>59</strong></td>
<td>Solutrean unifacial point</td>
<td>1</td>
</tr>
<tr>
<td>Assemblage portion</td>
<td>17.1</td>
<td><strong>Totals</strong></td>
<td>2 (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assemblage portion (%)</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Tool portion (%)</td>
<td>1.0</td>
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Table 5. Cores and Nucleiform Endscrapers

Cores are summarized based on the number of platforms. Cumulative removal summarizes the total number of removals taken from all cores in each platform category. Cumulative hinge or step quantifies the number of those removals that have hinge or step terminations. The error rate is the portion of cumulative removals that have hinge or step terminations.

<table>
<thead>
<tr>
<th>No. of Platforms</th>
<th>Count</th>
<th>Cumulative Removals</th>
<th>Cumulative Hinge or Step</th>
<th>Error Rate (%)</th>
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<tr>
<td>Nucleiform endscrapers</td>
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<td>1</td>
<td>7</td>
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</tr>
<tr>
<td>2</td>
<td>5</td>
<td>26</td>
<td>10</td>
<td>38.5</td>
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<tr>
<td>3</td>
<td>1</td>
<td>8</td>
<td>6</td>
<td>75</td>
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<tr>
<td>4</td>
<td>1</td>
<td>8</td>
<td>7</td>
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<td><strong>Total</strong></td>
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<td>Cores</td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>18</td>
<td>8</td>
<td>44</td>
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<tr>
<td>2</td>
<td>7</td>
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<td>21</td>
<td>91</td>
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<tr>
<td>3</td>
<td>3</td>
<td>15</td>
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</tr>
<tr>
<td>4</td>
<td>3</td>
<td>20</td>
<td>19</td>
<td>95</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>23</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>
Table 6. Lithic Raw Materials from Urtiaga Level F

Unidentified flints are distinguished based on their reference letter in the ad hoc raw material collection Fontes created for the Vasco-Cantabrian region (information are available upon request). Distance measures are approximate linear ranges from Urtiaga. Counts are the total number of artifacts identified in each raw material; tools are inclusive in this number. Weight is cumulative for all artifacts manufactured in each raw material. Assemblage portion was determined based on toolstone weights. There are five different unidentified stones. Bidache, microcrystalline, and chalcedonic flysches outcrop in southwest France and in Kurzia, near Bilbao, Spain. Stemming from direct comparisons with A. Tarriño’s reference collection made for Aitzbitarte III, the materials from Urtiaga are from the French outcrop based on matching macroscopic fossilized sponge spicules (see Tarriño (2009) and (2012), for further information about French and Spanish flysch outcrops). It is additionally possible that flysches were procured from coastal outcrops that are now submerged. Raw materials were not identified for microdebitage <1cm.

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Distance (km)</th>
<th>Count (#)</th>
<th>Tools (#)</th>
<th>Weight (g)</th>
<th>Portion</th>
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<tr>
<td>Major Toolstones</td>
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<tr>
<td>Chalcedonic Flysch</td>
<td>100</td>
<td>517</td>
<td>123</td>
<td>2148.9</td>
<td>37.3</td>
</tr>
<tr>
<td>Urbasa Flint</td>
<td>50</td>
<td>315</td>
<td>71</td>
<td>990.8</td>
<td>17.2</td>
</tr>
<tr>
<td>Microcrystalline Flysch</td>
<td>100</td>
<td>148</td>
<td>43</td>
<td>766.4</td>
<td>13.3</td>
</tr>
<tr>
<td>Gaintxurizketa Flysch</td>
<td>40</td>
<td>180</td>
<td>23</td>
<td>590.9</td>
<td>10.3</td>
</tr>
<tr>
<td>Chalosse Flint</td>
<td>150</td>
<td>91</td>
<td>22</td>
<td>318.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Treviño Flint</td>
<td>70</td>
<td>95</td>
<td>28</td>
<td>266.2</td>
<td>4.6</td>
</tr>
<tr>
<td>Flint VC_F110</td>
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<tr>
<td>Bidache Flysch</td>
<td>100</td>
<td>31</td>
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<td>151.9</td>
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<tr>
<td>Flint VC_F117</td>
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<tr>
<td>Flint VC_F118</td>
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<tr>
<td>Flint VC_F116</td>
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<td>--</td>
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<td>Flint VC_GF_5</td>
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<tr>
<td>Mudstone/Lutite</td>
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<td>3</td>
<td>2</td>
<td>74.1</td>
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<tr>
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<td>Unclassified Microdebitage</td>
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Table 7. Fauna and Malacofauna from Urtiaga Level F.
Data are from Altuna (1972) and Altuna and Mariezkurrena (2010). Assemblage portion is based on the NISP.

<table>
<thead>
<tr>
<th>Faunas</th>
<th>Common Name</th>
<th>NISP</th>
<th>MNI</th>
<th>Adults</th>
<th>Juveniles</th>
<th>Portion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervus elaphus</td>
<td>Red deer</td>
<td>557</td>
<td>17</td>
<td>11</td>
<td>6</td>
<td>60.1</td>
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<tr>
<td>Capra pyrenaica</td>
<td>Ibex</td>
<td>112</td>
<td>9</td>
<td>9</td>
<td>--</td>
<td>12.1</td>
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<tr>
<td>Rupicapra rupicapra</td>
<td>Chamois</td>
<td>73</td>
<td>4</td>
<td>4</td>
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<td>7.9</td>
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<td>Vulpes vulpes</td>
<td>Fox</td>
<td>67</td>
<td>6</td>
<td>--</td>
<td>--</td>
<td>7.2</td>
</tr>
<tr>
<td>Capreolus capreolus</td>
<td>Roe deer</td>
<td>43</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td>4.6</td>
</tr>
<tr>
<td>Bison priscus &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bos primigenius</td>
<td></td>
<td>20</td>
<td>2</td>
<td>2</td>
<td>--</td>
<td>2.2</td>
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<tr>
<td>Arvicola terrestris</td>
<td>European water vole</td>
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<td>4</td>
<td>--</td>
<td>--</td>
<td>1.7</td>
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<tr>
<td>Rangifer tarandus</td>
<td>Reindeer</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1.3</td>
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<td>Equus caballus</td>
<td>Horse</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>--</td>
<td>0.9</td>
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<td>European polecat</td>
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<td>2</td>
<td>--</td>
<td>--</td>
<td>0.8</td>
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<td>European mole</td>
<td>3</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>0.3</td>
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<tr>
<td>Panthera leo</td>
<td>Lion</td>
<td>3</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>0.3</td>
</tr>
<tr>
<td>Lepus sp.</td>
<td>Hare</td>
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<td>1</td>
<td>--</td>
<td>--</td>
<td>0.2</td>
</tr>
<tr>
<td>Mustela erminea</td>
<td>Stoat</td>
<td>2</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>0.2</td>
</tr>
<tr>
<td>Ursus spelæus &amp;</td>
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<tr>
<td>Ursus arctos</td>
<td>Cave bear</td>
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<td>1</td>
<td>--</td>
<td>--</td>
<td>0.1</td>
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<tr>
<td>Felis lynx</td>
<td>Lynx</td>
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<td>--</td>
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<td>0.1</td>
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<td><strong>Total</strong></td>
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<th>MNI</th>
<th>Portion</th>
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<td>Patella sp</td>
<td>Limpet</td>
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<td>44</td>
<td>38</td>
</tr>
<tr>
<td>Littorina obtusata</td>
<td></td>
<td>45</td>
<td>44</td>
<td>38</td>
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<td>Littorina littorea</td>
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<td>22.9</td>
</tr>
<tr>
<td>Osilinus lineatus</td>
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<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
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<td>Cerastoderma sp</td>
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<td>1</td>
<td>0.8</td>
</tr>
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<td><strong>Total</strong></td>
<td></td>
<td>118</td>
<td>115</td>
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**Table 8.** Reduction stages and Raw Material Composition in sampled contexts.

*Reduction stages are abbreviated: all (A), early (E), middle (M), and late (L).*

<table>
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<th>Raw Material</th>
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<th>Stage</th>
<th>%</th>
<th>Stage</th>
<th>%</th>
<th>Stage</th>
<th>%</th>
<th>Stage</th>
<th>%</th>
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<tbody>
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<td>4.270</td>
<td></td>
<td>4.310</td>
<td></td>
<td>6.325</td>
<td></td>
<td>6.385</td>
<td></td>
<td>8.400</td>
<td></td>
<td>8.460</td>
<td></td>
</tr>
<tr>
<td>Bidache flysch</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>M</td>
<td>6.5</td>
<td>M</td>
<td>4</td>
<td>M</td>
<td>2.4</td>
</tr>
<tr>
<td>Chalosse flint</td>
<td>M</td>
<td>2.4</td>
<td>M</td>
<td>7.4</td>
<td>M</td>
<td>13.5</td>
<td>L</td>
<td>5.3</td>
<td>M</td>
<td>1.1</td>
<td>M</td>
<td>3.5</td>
</tr>
<tr>
<td>Chalcedonic flysch</td>
<td>E/M</td>
<td>31</td>
<td>A</td>
<td>29.4</td>
<td>M</td>
<td>28.7</td>
<td>M/L</td>
<td>22.6</td>
<td>M/L</td>
<td>37.5</td>
<td>M</td>
<td>48.6</td>
</tr>
<tr>
<td>Gaintxurzketa flysch</td>
<td>M</td>
<td>16.8</td>
<td>M</td>
<td>8.5</td>
<td>M</td>
<td>4</td>
<td>M/L</td>
<td>18</td>
<td>M</td>
<td>11.4</td>
<td>M</td>
<td>7.5</td>
</tr>
<tr>
<td>Microcrystalline flysch</td>
<td>M</td>
<td>4.5</td>
<td>L</td>
<td>19.4</td>
<td>M</td>
<td>13.2</td>
<td>M</td>
<td>9.2</td>
<td>M</td>
<td>3.9</td>
<td>M/L</td>
<td>20.4</td>
</tr>
<tr>
<td>Treviño flint</td>
<td>M</td>
<td>14.6</td>
<td>M</td>
<td>3.5</td>
<td>M</td>
<td>10.7</td>
<td>M</td>
<td>3.7</td>
<td>M</td>
<td>7.1</td>
<td>M</td>
<td>6.4</td>
</tr>
<tr>
<td>Urbasa flint</td>
<td>A</td>
<td>25.5</td>
<td>L</td>
<td>21.1</td>
<td>M</td>
<td>27.9</td>
<td>M</td>
<td>19.8</td>
<td>M</td>
<td>7.9</td>
<td>M</td>
<td>6.4</td>
</tr>
<tr>
<td>All other toolstones</td>
<td>--</td>
<td>5.3</td>
<td>--</td>
<td>10.7</td>
<td>--</td>
<td>2.1</td>
<td>--</td>
<td>14.8</td>
<td>--</td>
<td>27.3</td>
<td>--</td>
<td>4.7</td>
</tr>
</tbody>
</table>
Table 9. Urtiaga Level F Tools in Sampled Contexts

Sample contexts are abbreviated by sector and depth as discussed in the text. Parenthetical values represent the distribution of tools on pieces classified as “Diverse”.

<table>
<thead>
<tr>
<th>Tool Type</th>
<th>4.270</th>
<th>4.310</th>
<th>6.325</th>
<th>6.385</th>
<th>8.400</th>
<th>8.460</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple endscraper</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Atypical endscraper</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Double endscraper</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Endscraper on flake</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Carinated endscraper</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Thick nosed endscraper</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Nucleiform endscraper</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>2</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Perforator-truncated piece</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Perforator-endscraper</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Perforator</td>
<td>1</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Atypical perforator</td>
<td>--</td>
<td>--</td>
<td>2 (2)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Microperforator</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
</tr>
<tr>
<td>Straight dihedral burin</td>
<td>--</td>
<td>--</td>
<td>(1)</td>
<td>--</td>
<td>--</td>
<td>1</td>
</tr>
<tr>
<td>Slanted dihedral burin</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Angle dihedral burin</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>(1)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Angle on break burin</td>
<td>(1)</td>
<td>(1)</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>(1)</td>
</tr>
<tr>
<td>Burin on oblique retouched truncation</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
</tr>
<tr>
<td>Transverse burin on notch</td>
<td>--</td>
<td>--</td>
<td>(1)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Multiple burin on retouched truncation</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Multiple mixed burin</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Flat face burin</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>(1)</td>
</tr>
<tr>
<td>Gravette point</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Completely backed blade</td>
<td>1</td>
<td>1 (1)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Partially backed blade</td>
<td>2</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Straight truncated piece</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
</tr>
<tr>
<td>Oblique truncated piece</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>2</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Concave truncated piece</td>
<td>--</td>
<td>1</td>
<td>1</td>
<td>--</td>
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<td>--</td>
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<tr>
<td>Convex truncated piece</td>
<td>--</td>
<td>--</td>
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<td>--</td>
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<tr>
<td>Bitruncated piece</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Continuously retouched piece 1</td>
<td>1</td>
<td>(1)</td>
<td>1 (2)</td>
<td>2 (2)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Continuously retouched piece 2</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Notch</td>
<td>3 (1)</td>
<td>1</td>
<td>1 (3)</td>
<td>1 (2)</td>
<td>--</td>
<td>4 (1)</td>
</tr>
<tr>
<td>Denticulate</td>
<td>1 (1)</td>
<td>--</td>
<td>(1)</td>
<td>2 (2)</td>
<td>1 (1)</td>
<td>4</td>
</tr>
<tr>
<td>Splintered piece</td>
<td>2</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>--</td>
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</tr>
<tr>
<td>Side-scaper</td>
<td>--</td>
<td>--</td>
<td>(1)</td>
<td>--</td>
<td>(1)</td>
<td>--</td>
</tr>
<tr>
<td>Raclette</td>
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<td>--</td>
<td>--</td>
<td>--</td>
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</tr>
<tr>
<td>Backed bladelet</td>
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<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Truncated backed bladelet</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Retouched bladelet</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Diverse</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Table 10. Maintenance in Vasco-Cantabrian Upper Solutrean and Initial Magdalenian Assemblages

Data are from: Rios-Garaizar et al. 2013°, Straus et al. 2014†, González Echegaray and Barandiarán 1981∆, and Straus and Clark 1986Ω. Burin rejuvenation refers to the percentage of burin spall that removed previously retouched edges. Bladelet production is the percentage of bladelets in the lithic debris assemblage (exclusive of microdebitage). Bipolar reduction is indicated by splintered pieces as a portion of the lithic debris assemblage (exclusive of microdebitage). Multi-platform core indicates the percentage of all core types with multiple platforms. Used debitage proportions the percentage of the lithic assemblage with regularized edge damage/use. Nucleiform endscrapers are marked by their percentage of the total number of cores. “Diverse”/Composite tools indicate the portion of the tool assemblage comprised by de Sonneville-Bordes and Perrot types 17-22 and 92. All site/landscape level attributes are marked as present (+), absent (-), or not applicable/indeterminate from published analysis (NA). *Percentage for Arlanpe includes all laminar debitage because analysts did not distinguish between blades and bladelets. ** Fontes’ (2014) analysis of Rascaño Levels 4/4b yielded significantly large quantities of bipolar debris that were not identified in analyses by González Echegaray and Barandiarán (1981); this value may underrepresent the assemblage.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Urtiaga F</th>
<th>Arlanpe II°</th>
<th>El Mirón 117-119.3†</th>
<th>El Rascaño 5∆</th>
<th>La Riera 17Ω</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lithic Industry</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burin rejuvenation (%)</td>
<td>25</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Bladelet production (%)</td>
<td>4</td>
<td>15*</td>
<td>37</td>
<td>NA</td>
<td>23</td>
</tr>
<tr>
<td>Bipolar reduction (%)</td>
<td>2</td>
<td>0.2</td>
<td>0.01</td>
<td>0.7**</td>
<td>0.1</td>
</tr>
<tr>
<td>Used debitage (%)</td>
<td>19</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Multi-platform cores (%)</td>
<td>54</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Nucleiform endscrapers (%)</td>
<td>38</td>
<td>0</td>
<td>17</td>
<td>42</td>
<td>21</td>
</tr>
<tr>
<td>“Diverse”/Composite tools (%)</td>
<td>20</td>
<td>17</td>
<td>1</td>
<td>7</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Site/Landscape</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diverse Sagaies</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Blank selection/transport</td>
<td>+</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Consistent site activities</td>
<td>+</td>
<td>NA</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Flint dependence</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>
Supplement A: Lithic Debris Analysis

In addition to the debris classification described in the main text, a series of qualitative and quantitative attributes were recorded for each lithic artifact:

(a) raw material type, which was determined using an *ad hoc* reference collection whose samples were then directly compared to a similar reference collection made by geologist A. Tarriño (2012) for Aitzbitarte III (a site located approximately 30km from Urtiaga cave) in order to make geographic source determinations. This reference assemblage included samples of Gaintxurizketa, Bidache, chalcedonic, and microcrystalline flyshes, and Chalosse, Treviño, and Urbasa flints;

(b) artifact size, which was recorded using a square centimeter size chart, and length, width, and thickness measurements (on whole debitage, tools, and cores) to the nearest millimeter;

(c) artifact weight, which was measured to the nearest 0.1 gram;

(d) manufacture variables, including debitage fragmentation (whole, proximal, mesial, distal, longitudinal or indeterminable), and, where applicable: platform type (following Andrefsky 2005), termination type (following Cotterell and Kamminga 1987), dorsal flake scar count (following Andrefsky 2005; whole debitage only), and dorsal cortex amount (modified from Andrefsky 2005 to consider four stages: absent, <1/3 exterior cortical surface, 1/3 to 2/3 cortical, and 2/3 to complete; whole debitage only);

(e) presence or absence of two taphonomic processes: patina and burning. Burning was distinguished based on the presence of crazing and pot-lidding;

(f) edge damage/use, which was measured in up to three locations on each artifact. Location was recorded (i.e., proximal, right margin, etc.) and type of use: flake snaps,
dulling, nibbling, and edge concavities (“half moons”). Each type of damage was recorded as continuous or discontinuous (e.g. continuous on the entire right margin vs. discontinuous on the distal portion of the left margin); and,

(g) for cores (and core tools), three additional variables were recorded: the number of platforms, the number of removals struck from these platforms, and the number of those removals that had hinge or step terminations.

These attributes, together with the debris classification, provide information about all stages of lithic technological organization at Urtiaga cave.
Supplement B: Toolkit Maintenance

The following assemblage features indicate toolkit maintenance in lithic reduction:

(a) *burin rejuvenation*, when burin blows removed previously retouched edges and thereby repurpose tool blanks;

(b) *bladelet production*, which utilizes raw material as it diminishes in size, avoiding toolstone waste;

(c) *bipolar reduction*, a manufacturing technique that can effectively reduce refractory and/or small raw materials, allowing toolstone to be processed even as its size and/or quality diminished within the mobile toolkit;

(d) *used debitage*, which demonstrate that groups intensified use of manufacturing debris beyond blanks that they modified into formal tools—available, suitably sized and/or shaped debitage cutting edges were utilized for expedient tasks;

(e) *multi-platform cores*, which indicate cores that were manufactured using exhaustive core reduction techniques that utterly depleted lithic raw materials;

(f) *nucleiform endscrapers*, whose manufacture repurposed exhausted cores into functional steep scraping tools (see Keeley 1988 and Domingo et al. 2012); and

(g) “*Diverse”/composite tools*, which efficiently combine formal tools on single blanks, (re)utilizing raw material.

Each of these traits is associated with raw material conservation; all are characteristics of LCM assemblages in Vasco-Cantabria (Fontes 2014a, 2014b; González Echegaray 1960; Straus et al. 2008). Additionally, four other traits testify to maintainable organizational systems:
(h) Diverse sagaies in toolkits, evidence that groups experimented with varying forms of antler insets before selecting the quadrangular cross-section design most common in the LCM. Sagaies were an essential component of the modular, maintainable Magdalenian weapon technology;

(i) blank selection and transport, wherein groups retained blanks in mobile toolkits for future use. These pieces would have not only made the toolkit a predictable resource, but also enabled non-specialists to select pieces from those already produced to retool in the event that an item broke or its use was depleted. Non-specialist toolkit maintenance is a major characteristic of maintainable technological organization (Bleed 1986);

(j) consistent site activities, which testify to groups not only maintaining their toolkits, but translating modular design to their mobility strategies, regularizing site use and site position in a settlement system; and

(k) flint dependence, wherein groups maintained the kinds of raw materials they used, and perhaps regularized toolstone access within a modular settlement system. Each of these traits is discussed in the main text in the context of Vasco-Cantabrian Initial Magdalenian/Upper Solutrean sites.
Chapter 3:
Lithic and Osseous Artifacts from the Lower Magdalenian Human Burial Deposit in El Mirón Cave, Cantabria, Spain

This chapter is a manuscript that was written by Lisa M. Fontes, Lawrence Guy Straus, and Manuel R. González Morales and was published in 2015 in the *Journal of Archaeological Science* special issue “The Red Lady of El Mirón Cave: Lower Magdalenian Human Burial in Cantabrian Spain”, volume 60, pages 99-111. Fontes wrote the article, with the exception of its introduction and section about osseous industry, which Straus wrote. Straus also did the osseous artifact analysis. González Morales provided small edits to the manuscript.

1. Introduction

El Mirón is a prominent cave located on the western cliff side of Monte Pando in the upper portion of the Asón river valley, outside the town of Ramales de la Victoria (González Morales and Straus 2005). The site was a location of repeated, functionally complex occupations during the Lower Cantabrian Magdalenian (LCM) period (c. 16-14,500 uncal. BP) (González Morales and Straus 2005; Straus and González Morales 2003, 2007, 2009, 2012). LCM deposits are distributed throughout the cave vestibule; these layers are generally thick, dark “chocolate” brown, highly organic deposits of silty clayey loam with limestone *éboulis*, water-worn cobbles, highly fragmented faunal remains (principally red deer and ibex), osseous artifacts, charcoal and ash hearths associated with anvils and fire-cracked rocks, lenses of yellow and red ochres, portable art objects, and high concentrations of lithic materials (Nakazawa et al. 2009; Straus and González Morales 2012; Straus et al. 2008). The Mirón LCM human burial was discovered in the vestibule rear in a small area (c. 2.5 m² for the area with concentrated
human remains within a total area of c. 4m²) behind a large, engraved block (Straus et al. 2011) (Fig. 1). Straus and González Morales, with Cuenca Solana (this issue), discuss the “Red Lady’s” discovery in detail, including its stratigraphic position, radiocarbon dates, and relationship to other Magdalenian units and materials in El Mirón. The human remains were recovered from a depression—both natural and artificial—and principally from Level 504, with a few being labeled “Level 505 or 506” because of the essential continuity of the sediment matrix between Levels 504 and 505. The burial pit had been dug into Level 505 and then filled with mixed sediments, with what is called Level 504 being fundamentally defined by the presence of abundant red ochre. The red ochre-stained sediments of Level 504 were discontinuous in the southern sector of the area (X-Y6/5), in part because of the presence of rodent burrows, but also because this area was peripheral to the burial per se. The stained sediments that both covered and surrounded

Fig. 1. Plan of El Mirón cave vestibule showing excavated areas. Lower Magdalenian contexts compared are highlighted: outer vestibule Level 15 (blue), mid-vestibule Level 312 (purple), and rear vestibule Level 504 (red). Cartography by Eduardo Torres, modified by L. Straus, R. Stauber, and L. Fontes.
the human remains contained many lithic and osseous artifacts typical of the LCM at the site, thus, it is not possible to affirm whether any of the items recovered were “offerings” or “grave goods”, although this would seem unlikely. However, because the deposit was first mixed by the digging of the burial pit and was later locally disturbed by rodent burrows, the possibility that some artifacts might have been deliberately placed alongside human bones remains plausible (although only 18 lithic artifacts, including ten flakes, two blades, one bladelet, two angular debris, and three tools—a denticulate, truncation, and perforator—had ochre traces and none are “out of the ordinary”). This paper demonstrates that: 1) osseous industries recovered from Level 504 are typical of LCM assemblages; 2) the abundant lithic artifacts indicate multiple manufacture stages using very high-quality flints, and are consistent with inter- and intra-site variability known for the LCM period; and 3) the rich LCM horizon extends to the rear of the El Mirón vestibule. In addition, the lithic assemblage of the burial layer (504) is compared with that of the immediately underlying level (505), with which it was partially mixed when the burial was made.

2. Methodology

Lithic materials less than one linear centimeter in size (except small bladelet tools, which were all individually analyzed) were classified and analyzed collectively as cortical and non-cortical trimming flakes and shatter. Lithic artifacts over one centimeter were analyzed using a combination of individual flake and aggregate methods that recorded various qualitative and quantitative data, including length, width, thickness, weight, patination, burning, and traces of use. All materials were classified using a debris typology that distinguished microdebitage (<1cm); cortical vs. non-cortical and
fragmentary flakes, blades (≥2cm length), and bladelets (<2cm); microburins; platform renewal flakes; splintered pieces; uni- and bi-directional crested bladelets; cortical and non-cortical chunks; and various categories of flake, blade, bladelet and mixed cores (following Straus et al. 2008). Raw materials were determined for lithic debris greater than one centimeter in size and for all formals tools using an *ad hoc* reference collection created during 17 years of excavations at El Mirón. This collection includes a total of 66 types of flints, limestones, quartzites, quartzes, calcites, mudstones, and other (rare) materials present at the site. All tools were classified using the de Sonneville-Bordes and Perrot (1954, 1955, 1956a, 1956b) Upper Paleolithic tool typology, which was modified to include “Juyo facies” bladelets as type 90 (instead of traditional Dufour bladelets), a standard typological modification for the Vasco-Cantabrian region, following González Echegaray (1985).

Osseous industries included needle fragments, a perforated tooth, a few perforated shells (described in detail by Gutiérrez-Zugasti and Cuenca-Solana, this issue), and several fragmentary antler *sagaies*. Bone points were classified as to their portion; base type; cross-section style, including presence/absence of grooves presumably for microlith insertion; and presence/absence of engraved “decorations”, which were described, if present. Metric variables (length, width, thickness) were also recorded.

### 3. Lithic Industry

#### 3.1 Lithic Materials and Densities

The lithic industry from El Mirón Level 504 is a total of 33,600 artifacts: 969 formal tools, 80 cores, 5,610 debitage, and 26,941 microdebitage. The overall densities of lithic artifacts in relation to the human remains recovered from Level 504, as well as
the lithic contents of underlying Level 505 are presented by sub-square in Fig. 2. Human remains from Level 504 are mostly concentrated in squares X7 and Y7, in the thickest (c.20 cm) portion of the wedge-shaped deposit; only seven elements were recovered from X or Y6 and no remains from the Red Lady were recovered from X/Y5 or W7 (see Geiling and Marín-Arroyo, this issue). Lithic artifacts were most densely concentrated in X and Y 6/5 (c. 9 cm thick), to the south of the human remains.

<table>
<thead>
<tr>
<th>Human Remains Density</th>
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Fig. 2. Sub-square lithic artifacts and human remains densities in El Mirón Levels 504 and 505. Percentages were determined based on sub-square portion of the overall lithic assemblage. W7D, X7B, and X7C are partial squares; squares are lettered left to right, north row then south row.

Microdebitage, which constitute 80% of the Level 504 lithic assemblage, strongly influence the overall lithic density plots (Figs. 2-4). Larger lithic artifacts, summarized by artifact type in Figs. 3 and 4, confirm the major concentration shown in Fig. 2 in Levels 504 and 505. There is a high density of tools in Level 504 subsquare Y6C, coupled with a relatively even distribution among subsquares in X and Y6/5. Cores from this level form two major groups in Y6C and X6C. While both clusters contain flake, prismatic bladelet, pyramidal bladelet, and mixed cores, Y6C (n=15) has predominately mixed (40%) and pyramidal bladelet cores (33%), while X6C (n=16) contains 31% flake cores and 38% pyramidal bladelet cores. Unfortunately, the core types are not
significantly varied enough so as to correlate them with any certainty to variations in debitage: both core groups indicate flake and bladelet production. Lithic density distributions from Level 505 echo those from Level 504, particularly in the debris locus

Fig. 3. Density breakdown of lithic artifacts from Level 504 by artifact type. Percentages were determined based on sub-square portion of the total material of each artifact type.

Fig. 4. Density breakdown of lithic artifacts from Level 505 by artifact type. Percentages were determined based on sub-square portion of the total material of each artifact type.

in subsquare Y6C. Overall, lithic artifact density sub-plots demonstrate a concentration of all types of lithic artifacts to the south of the human remains recovered from X and Y7.
Additionally, the closely correlated spatial distribution between Level 504 and that of underlying Level 505 suggests a degree of spatial integrity associated with patterned activities within the X/Y6 area. Those materials recovered in the area of concentrated human remains are quite small—the majority are microdebitage or other items under two centimeters in size. Only 80 tools were found from Level 504 in this area; 69% of these were bladelet tools made on high quality raw materials. Relative to the rest of the assemblage, these materials are not unique. Thus, a direct relationship between the lithic artifacts and human remains is questionable (i.e., that the lithics were deliberately placed atop or alongside human remains), because of the significant concentration of all lithic artifact types against the south cave wall.

The complicated stratigraphic structure of the Level 504 deposit—composed of thin, easily disturbed patches and lenses whose common denominator was ochre staining—does little to clarify the kinds of activities that could have resulted in the separate concentrations of lithics and human remains. While the strong pattern shown in density plots from Level 504 mirrors similar lithic concentrations in Level 505 and those distinguished in preliminary analyses by Fontes et al. (2012, 2013) from the Mirón outer vestibule, the integrity of this concentration can be drawn into question because of the level’s sedimentary structure and formation processes. There are two principal issues that effect its interpretation:

(1) Level 504 sediments within the X/Y7 squares are presumed to be “fill” for a wedge-shaped depression in which the human bones were placed because they are stained with ochre pigment and sparkling hematite crystals. Some of this “fill” appears to have been removed from the X/Y7 area (from underlying Level 505, whose faunal
remains indicate darker manganese staining than those from Level 504, thus indicating
mixed layers), to create a depression and/or augment a natural basin interlaid between the
sloping bedrock and the fallen engraved block (see Marín Arroyo, this special issue);

(2) Level 504 varied substantially in thickness and character—with some areas
being tinted a deeper red color (in X/Y7); others sparkling from hematite crystals; some
with dense, localized ochre patches, as if remnants of a processing area (in X6); and still
other micro-lenses were difficult to identify during excavation (see Seva et al., this issue).
The thickest portions of the deposit contain the fewest lithic artifacts and the densest
concentrations of ochre staining and hematite crystals.

With these two factors as a basis, there are two possible interpretations of the lithic
concentration in Level 504, X/Y6 and X/Y5:

(1) the lithic cluster is the result of in situ flintknapping and was minimally altered
in terms of its contents by the creation and/or infilling of the burial depression; lithics
recovered from thin lenses of ochre-stained sediments contributed minimally to the
artifact concentration in X and Y6/5.

(2) the lithic concentration was directly related to creation of the burial depression.
When materials were first removed from X/Y7, larger, heavier pieces were “filtered”
from sediments and deposited together against the wall such that only the smallest
materials were reintegrated into the stained sediment mixture that was returned to squares
X and Y7. The lithics were spatially and temporally displaced.

The inability to distinguish how lithic artifacts in the Level 504 depression fill have been
altered through cultural (long bone removal and re-burial) and natural (carnivore
scavenging and rodent burrowing) activities throws their absolute depositional integrity
into question (see Geiling and Marín Arroyo, this issue; Marín Arroyo, this issue; and Straus et al. 2011). However, the artifacts were related through at least some shared shades of ochre staining, and thus were interpreted as a single unit in this analysis—a unit that provided important information about lithic manufacture, composite tool industries, and use of El Mirón cave, despite its contextual uncertainties.

3.2 Lithic Manufacture

3.2.1 Cores

Eighty cores were recovered from Level 504 and classified based on the shapes of the final removals on each core’s face. There are 22 flake cores, one prismatic blade core, 11 prismatic bladelet cores, 22 pyramidal bladelet cores, and 24 mixed cores (with both blade(let) and flake removals). Level 505 provided a similarly distributed core assemblage (n=66) (Table 1). Together, the cores from Levels 504 and 505 demonstrate a combination of chaînes opératoires—flake, shaped-core blade(let), and mixed flake/blade(let)—that emphasize bladelet manufacture as a focus of lithic reduction at Mirón. However, the high percentage of flake debitage at Mirón (Table 1) contrasts the high percentage of bladelet manufacture demonstrated among the cores (71% of cores in Level 504 and 65% of those in Level 505 have one or more bladelet removals). This, together with the presence of mixed cores (30% of all cores), indicates that bladelet manufacture was primarily a late-stage reduction strategy, secondary to flake removals that trimmed larger cores to sizes suitable for bladelet blank production. As blade cores and debitage are comparatively rare to flakes and bladelets (Table 1), it is possible that blades served the same purpose as flakes in shaped-core reduction sequences—trimming minimal excess material on the outer core and preparing the core shape for bladelet
reduction. The prevalence of bladelet reduction and diversity of core types is typical of the Lower Cantabrian Magdalenian at El Mirón (Straus et al. 2008). It is, however, worth noting that the core assemblage in Levels 504 and 505 is relatively small compared to that recovered from the Lower Magdalenian Level 312 in the Mirón mid-vestibule sondage (Fig. 1), a one square meter pit that yielded 257 cores, 83% of which had at least one bladelet removal (Straus et al. 2008). These assemblage sizes could be correlated to differential spatial use of the Mirón vestibule or the aforementioned depositional disturbances in the burial area, though neither factor diminishes the emphasis on late-stage bladelet production evident in the cores from both excavation areas.

3.2.2 Debitage

With nearly 60% of the debitage assemblage >1cm in size, flakes are the most prevalent debris type in Level 504, followed by bladelets (16%) and angular chunks (17%). Blades, burin spalls, platform renewal flakes, and crested blades are present in small quantities. There are no microburins. The majority of debitage are non-cortical (69%); primary decortications are rare among flake and blade(let) debitage. A third of flakes and blades are cortical, consistent with these removals playing equal roles in core construction for later bladelet removals. Only ~13% of bladelets have cortex, consistent with cortical surfaces being removed before bladelets were produced. Additionally, nearly half of angular debris is cortical, consistent with the use of hard- and soft-hammer production techniques in early stage reduction before executing pressure techniques to manufacture standardized bladelet blanks. These results are again consistent with the Level 504 cores: flakes, blades, and angular waste by-products could constitute evidence of early-stage reduction of joint chaînes opératoires with bladelet end-products.
Debitage types present in small amounts—burin spalls (n=85), crested blades (n=6), and platform renewal flakes (n=58)—are evidence of early and middle stages of lithic reduction: crested blades were used to form initial blade removals on a core face while platform renewal flakes rejuvenated cores for further reduction. Burin spalls also attest to blank renewal and creation of dihedral surfaces. Approximately 20% of burin spall and platform renewal flakes are cortical, while for crested blades the cortical percentage is a higher 67% (Table 1). These values, while based on small sample sizes of each artifact type, are consistent with initial reduction stages that removed cortical surfaces to prepare further reduction (crested blades), or to rejuvenate surfaces that had been previously modified (platform renewal flakes and burin spall). Furthermore, the small number of crested blades is consistent with observed low percentages of blade cores and debitage in the Level 504 lithic assemblage. The small (crested) blade amounts provide further evidence of the prominent use of flake-to-bladelet chaînes opératoires at Mirón, instead of blade-to-bladelet sequences (or, at least those prepared using the crested blade technique). Overall, Level 504 debitage and cores suggest the same reduction sequences, which could indicate that the lithics were left relatively undisturbed when the burial depression was formed, and/or that the displaced lithics were the result of temporally and spatially constrained flintknapping activities in the Mirón rear vestibule. Comparisons of Level 504 debitage with those from Level 505 provide further support of these hypotheses: aside from slight percentage differences (approximately or <5%) among plain flake, secondary decortication flake, whole and fragmentary plain bladelet, and cortical chunk debris categories, the overall distribution of lithic categories is essentially identical between these levels (Table 1). When coupled with the spatial
correlations shown in Figs. 2-4, there is strong evidence that Levels 504 and 505 were not just sequentially, but also behaviorally, contiguous.

3.3 Lithic Tools

LCM lithic technology is known for its regional inter-site variability, which could be related to Last Glacial mobility, raw material accessibility and/or site activities, among other interpretations (Freeman and González Echegaray 2001; Freeman et al. 1998; González Echegaray 1960, 1980; Straus 1992, 2013; Utrilla 1981). To determine if the tools from Level 504 were simply typical of the LCM at El Mirón—and thus not “special” or indicative of “grave goods”—a comparison was made between tools from the burial (15,740±40 BP) and three other areas within the site (Fig. 1; Table 2): those from the underlying Level 505; the temporally equivalent, artifactually abundant mid-vestibule sondage Level 312 (1m²; 15,850±170 BP), and a later Lower Magdalenian outer vestibule Level 15 (9m²; 15,010±260 and 15,220±300 BP) (Straus and González Morales 2003, 2007; Straus et al. 2011). Relative to these three other contexts, Level 504 is exceptionally rich, with 265% more tools than Level 505, 167% more than Level 312, and 475% more than Level 15 (Table 2). Despite the quantity of material in Level 504, its tool assemblage is largely similar to the three Mirón contexts and typical LCM variation.

3.3.1 Endscrapers, Perforators, and Burins

Level 504 is not particularly rich in endscrapers, though the assemblage contains several nucleiform endscrapers, an artifact marker of the LCM (Table 2; Keeley 1988; Straus 1992; Utrilla 1981). Endscrapers are not a significant component of the Level 505 tool assemblage—even nucleiform endscrapers are few in number. Level 312 has much
higher percentages of this artifact type relative to endscrapers overall (72%), while Level 15 contains equal numbers of nucleiform endscrapers and endscrapers-on-flakes. Other endscrapers are a minor portion of the Level 504 (4%) and Level 505 (3%) tool assemblages, while Levels 312 (12%) and 15 (20%) are richer in this artifact type. Perforators comprise small percentages of Levels 504, 505 and 312 (~2-3%) and are slightly more prominent in Level 15 (6%). In all contexts except Level 505, “becs”, or atypical perforators, are the most common type. Level 504 also has several microperforators, which were also encountered in Levels 505 and 312, but not in Level 15; perforator diversity and distribution is similar in Levels 504 and 312. Finally, burins make up nearly a tenth of the Level 15 tool assemblage, but only small portions of artifacts from Levels 504, 505, and 312. Various dihedral and truncated burins were found in each context; angle-on-break burins are the most common burin type. These data show that while the representation of endscrapers, perforators, and burins is variable among these contexts, LCM diagnostic artifacts—nucleiform endscrapers and angle on break burins—are present in each level (Table 2).

3.3.2 Microliths

Geometric microliths and bladelet tools represent significant differences among these four contexts: Level 15 lacks geometric microliths, while in Levels 504, 505, and 312 they—together with backed bladelets—are important elements of each assemblage. Diverse microliths were recovered from Level 504, though some—denticulated bladelets, trapezes, and notched bladelets—in small numbers (Table 2; Fig. 5). The Level 504 microlithic assemblage is rich in triangles, circle segments, and very small, diminutive retouched bladelets consistent with the “Juyo facies” described by González Echegaray
Yet another tool type distinguishes Level 504 from the other contexts: the presence of backed Gravette and microgravette points, another important blade(let) based tool group that were presumably weapon tips. Level 505 mirrors 504 in its microlithic assemblage diversity, though it is not as rich overall and lacks “Juyo” bladelets. The Level 504, 505 and 312 tool assemblages are similarly microlith-focused, though Level 504 is the most diverse among these samples.
3.3.3 “Various” Tools and Continuously Retouched Pieces

Notches, denticulates, and sidescrapers—termed “Various Pieces” in the de Sonneville Bordes and Perrot typology—are components of each Mirón context. They make up an exceptionally large portion of the Level 15 assemblage (30%) compared to Levels 504 (8%), 505 (9%) and 312 (13%). No raclettes, a tool typical of French earliest Magdalenian (Badegoulian) assemblages and rare in Cantabria (Straus and González Morales 2012), were found in Levels 504, 505, and 312, though one was recovered from Level 15. Continuously retouched pieces—flakes or blades retouched on one or two sides, and usually dulled through use—were found in all four levels in similar percentages (Table 2). Despite differing concentrations, the ubiquity of these tools in all four contexts testifies to their importance, even in blade(let)-focused LCM assemblages.

3.3.4 Other Tool Categories

Small percentages of these Mirón assemblages are comprised of truncated pieces, Solutrean pieces, and/or “diverse” (Table 2). Truncations of various shapes were found in all four areas of the Mirón vestibule, though in small numbers in each assemblage. Solutrean pieces (fragments of points) were recovered in small numbers from Levels 504, 505, and 15. Finally, “diverse”—a catch-all category for composite tools not accounted for by the de Sonneville- Bordes and Perrot types—are small components of the Level 15, 504, and 505 tool assemblages, but are absent from Level 312. As these tool categories are represented by such small quantities in each level’s assemblage, the comparisons that may be drawn between them are insignificant relative to other tool categories.
3.3.5 Tool Assemblage Summary

Half of the lithic tool assemblage from Level 504 consists of bladelet tools, with secondary foci of geometrics, continuously retouched pieces, and various pieces, all c.10% of the assemblage. Bladelet tools are equally significant in Level 505 (47%); backed pieces (18%)—principally completely and partially backed blades—and various pieces (9%) are secondary groups. Level 312 is similarly bladelet tool-focused, with secondary groups distributed among endscrapers, continuously retouched pieces, and various pieces. Finally, the Level 15 tool assemblage is more diverse: 30% various pieces and 20% endscrapers, with three secondary groups—burins (9%), continuously retouched pieces (11%) and bladelet tools (8%) (Table 2). Various and continuously retouched pieces always form primary or secondary foci in El Mirón LCM assemblages, regardless of the proportion of bladelet tools in the sample. These tool assemblage comparisons confirm that the materials from Level 504 are consistent with others contexts from the LCM period, further implication that these materials were probably not “offerings”, but simply remnants of economic activities typical of Last Glacial occupations in El Mirón.

Intra-site comparison of lithic tool assemblages has provided data that improve archaeological understanding of LCM deposits in El Mirón cave. Levels 504, 505, and 312, which represent roughly contemporaneous occupations, differ from Level 15, a slightly later LCM occupation. Additionally, Level 312 has long been considered equivalent to outer vestibule Level 17 (another exceptionally rich Mirón LCM deposit) both depositionally and temporally, through several radiocarbon assays (Straus and González Morales 2007). The similarity between Levels 312, 504 and 505 implies that
the intense occupations that formed most abundant sections of the LCM palimpsest stretched the length of El Mirón cave in similarly—and extraordinarily—high densities. While each context likely represents multiple discrete, patterned occupations, together Levels 504, 505, 312, and 15 summarize major LCM tool variation previously demonstrated at other Cantabrian sites. El Juyo Level 4, an internally diverse deposit in a coastal plain cave known for its rich bladelet tool assemblage (Freeman et al. 1998; Freeman et al. 1988; González Echegaray and Freeman 2006), is largely similar to Mirón 312, 504, and 505. Altamira and El Rascaño, also two central Cantabrian sites (the former on the coastal plain, the latter in the adjacent montane zone), are broadly comparable to Mirón Level 15, but are lacking substantial quantities of bladelet tools (Freeman and González Echegaray 2001; González Echegaray and Barandiarán 1981). In El Mirón, the difference between Levels 312/504/505 and 15 might represent gradual change in the activities conducted during LCM occupations and as settlements in the Asón basin subsequently shifted to different cave sites at lower elevations (El Horno, El Valle) as part of a changing settlement strategy that brought with it a greater influence of Pyrenean groups—evidenced especially in portable art objects recovered from Middle and Upper Magalenian occupations, though not significantly at El Mirón (at least in the areas excavated) (Corchón 1995; García Moreno 2007; González Morales and Straus 2012; González Sainz and Utrilla 2005; Straus 2013). On the other hand, the difference in bladelet technology could be due to functionally distinct activity areas (or sampling vagaries) within the Mirón cave vestibule, rather than temporal trends.
3.4 Lithic Raw Materials

The El Mirón lithic raw material reference collection includes nine categories of tool-stone:

1. Group A, a collection of very high-quality, Basque-region flints that outcrop c.50-70 km from Mirón;
2. Group B, a variably colored, always high-quality flint category, also probably from flysch outcrops along the present Basque coast;
3. Ungrouped flint types, which represent some 30 distinguishable materials;
4. Unknown flints—rare materials that are unlike Groups A or B or the defined but ungrouped flint types;
5. Limestones;
6. Mudstones;
7. Quartzes and calcites;
8. Quartzites;
9. All other unidentified stones, which do not resemble any samples in the reference collection.

Group A flints dominate the Level 504 lithic assemblage among all artifact types; half of the tools recovered were made using Group A flints (Table 3) as well as half of the cores with blade(let) removals (n=58). Other toolstones are distributed similarly in all lithic groups: high-quality Group B flints at 25-29% of the assemblage; ungrouped flints—preferred over the lower-quality raw materials—approximate 17% of each lithic group (Table 3). The raw material distribution shows clear preference among Lower Magdalenian knappers for the highest quality flints, and as material quality decreases, its
presence in the assemblage diminishes. Additionally, while debitage and tools that were manufactured using low quality raw materials were recovered from Level 504, these materials were not present in the core assemblage (Table 3). Thus, these coarser materials may have been initially reduced elsewhere and their blanks and tools then transported to increase transport weight efficiency (see Beck et al. 2002; Bettinger et al. 1997; Metcalfe and Barlow 1992). Early-stage reduction outside of El Mirón is also supported by the rarity of primary decortication flakes in the Level 504 assemblage; both local, low-quality raw materials and distant, very high-quality materials were trimmed to decrease weight and thereby ease transport across the rugged Cantabrian landscape.

The raw materials identified in Level 505 show some important differences to those from 504. Among cores, ungrouped flint types are more common, seemingly at the expense of Group B flints (Table 3). This trend follows among debitage and tools: Group B flints are less common in Level 505 than they are in Level 504. Among all lithic artifact categories in Level 505, unidentified stones comprise a small portion of the raw materials—12% of cores, 9% of debitage, and 4% of tools (Table 3). Though discerning analytic nodules is difficult for unidentified stones (unknown quartzites, mudstones, limestones, etc. are grouped together in this catch-all category), when taken as a single unit these materials reflect reduction sequences that were geared toward flake-to-bladelet production and which yielded bladelet and flake tools. Finally, debitage from Level 505 show greater percentages of diverse raw material types—unknown flints, quartzites, quartzes, and unidentified stones—than the same artifact types in Level 504 (Table 3). These distinctions in lithic toolstones constitute a small—but nonetheless significant in terms of provisioning and consequently, LCM mobility—difference in the Level 504 and
505 lithic assemblages. Additionally, despite the varying raw materials, the behavioral patterns in lithic reduction remain nearly identical between the two levels: flakes and bladelets were the foci of both assemblages (Table 1).

In addition to the worked lithic artifacts, it is worth noting that Level 504 also yielded a large quartz crystal in close association with human bones in square X7D, whose weight was three grams and dimensions were 12x11x4 mm. This object, like the perforated bivalve shell found in the same area at the contact between Levels 502 and 504, could conceivably have been a grave offering, although this is impossible to prove.

4. Osseous Industry

This section presents a collective summary of the osseous industry recovered from the human burial area in El Mirón. Pending further detailed taphonomic analyses, especially of the degree of manganese coating evident on the surface of the sagaies, item provenience is based on artifact labels made during excavation and does not account for the post-depositional mixing that occurred between Levels 504 and 505 during the activity processes linked to burial and re-burial of the remains, as demonstrated by Marín Arroyo’s (this issue) taphonomic analysis.

4.1 Antler sagaies

Thirty-one fragments of antler sagaies (points) were recovered from Level 504. Seven fragments are proximal, 18 mesial, and six distal. Among proximal fragments, three are single-bevel bases, two are double-bevel bases, one has a rounded base, and one is indeterminate (see samples in Fig. 6). The fragment sections can be summarized as follows:
Fig. 6. Antler points (sagaiés) and decorated bone (X6, no. 710) from Level 504, the burial layer. Drawings by Luis Teira.

—nine have a quadrangular sections, one of which has a shallow longitudinal groove on each of two opposing surfaces;

—six are oval section, and one of these also has a single shallow longitudinal groove;
—five have round sections (one of which is centrally flattened);
—three have a plano-convex section (but these are single-bevel bases, so were in fact probably round- or oval-section);
—five are plano-convex, two of which have longitudinal grooves along the convex surface or along both sides and one of which has a shallow, narrow longitudinal groove along each of the two sides of its bevel base;
—one is plano-convex because it is the mesial part of a centrally-flattened piece;
—one round- or oval- section piece has deep, longitudinal grooves along both top and bottom surfaces;
—one was either round- or plano-convex in section, but the “flat” surface is too badly eroded to be certain of the original state.

The six grooved sagaies were undoubtedly fitted with bladelet barb or cutting elements. One of the double-bevel bases has a longitudinal groove on one bevel, diagonal lines across the other bevel and on one side. Another double-bevel base has diagonal lines across one bevel and a “W”-shaped engraving on the other bevel. There are no “anti-skid” marks on the central flattenings of the two points of that type.

Widths of the sagaies range from 3-12 mm and thicknesses from 3-11 mm. Cross-section areas range from 9-132 mm². The average is ~45 mm², with an essentially unimodal distribution centered around 50 mm² and a very long tail composed of four very “fat” sagaies. At the “skinny” end there are eight very gracile items that could be called “fine points”.

Not counting the “microlith insert” grooves and the “anti-skid” bevel-base lines, there are eight pieces with engraved “decorations”. One of the centrally flattened sagaies
has five “X”es on the convex face. A square-section piece has parallel lines on one face. The eroded round- or plano-convex section piece has three transversal lines on one side. An oval-section piece has a longitudinal line on one edge and another on one face. One small, square-section piece has a longitudinal line on each of three faces and transversal lines on the fourth face. One round-section piece has longitudinal lines crossed by two sets of diagonal lines on one face and another round-section item has a thin longitudinal line on one face and fine diagonal lines on another. There are a few marks on other pieces that could be decorations or manufacturing “accidents”.

The diversity of cross-sections (but with many quadrangular ones) and sizes, the presence of several longitudinally grooved pieces and of a centrally flattened one, plus the kinds of engraved decorations are typical of the Lower Magdalenian in El Mirón and in Cantabria in general (González Morales and Straus 2005; Straus and González Morales 2012).

4.2 Other Osseous Artifacts

Level 504 yielded three mesial and two distal fragments of bone needles, plus three other problematic distal fragments and a third indefinite fragment. No needle “eye” was found. There is also a large (140 x 33 x 8mm) mesial rib fragment of an ungulate (larger than red deer and probably horse) that has a polished beveled end classifiable as a spatula. This item is slightly stained with red ochre and bears small hematite crystals, as do other bone artifacts—simply from having been in the ochre-rich Level 504. Less certain is a split section of a flat long bone from an ungulate that has a canted polished end that might be a kind of knife. Another split, half-round section ungulate long bone is bifacially battered/splintered at one end and looks like a “scoop”. The osseous industry
of Level 504 is rounded out by the presence of a small probable bird bone tube (split) mesial fragment (L=5.7 mm, W=4.4 mm, T=2.6 mm) with many very fine transversal engraved lines on one face. There is a perforated incisor (probably of an ibex) and two fragments of antler blanks. Gutiérrez-Zugasti and Cuenca-Solana (this issue) describe the few mollusk shells found in this area, including perforated *Littorina* and *Trivia* shells from Level 504 and a perforated bivalve (from Level 502.1 and thus probably unrelated to the burial unless displaced by post-depositional disturbance such as by rodents).

4.3 Relation of Osseous Artifacts to Human Remains

The fact that there are no whole *sagaies* or needles (and no fragments come even close to completeness) suggests that these were not “grave goods”. The absolute scarcity of perforated objects—a single caprid incisor and the two shells—is very striking in comparison, for example, to the large numbers of perforated items from the Solutrean levels and non-burial Lower Magdalenian levels. Such objects are often fairly common in normal “residential” levels (e.g. see Fig. 7), again suggesting that the artifact assemblages of the Level 504 fill reflect activities unrelated to the burial. The only clear exception to this observation is the large amount of red ochre that stains much of Level 504, although it is also true that lumps of red ochre and thin, localized lenses or patches of ochre powder were often found on Lower Magdalenian living floors of both the vestibule front and rear areas.

4.4 Osseous Artifacts from Underlying Level 505

Twelve antler *sagaies* (all fragmentary) were recovered from Level 505, into which the “grave” may have been partially dug. They are in general similar to the finds from Level 504, but there are no very “fat” *sagaies*. The average cross-section area of
Fig. 7. Antler points (sagaies) from Levels 503 and 506, respectively above and below the burial layer. Drawings by Luis Teira.

these projectiles (including two pieces that could be classified as “fine points”) is 53mm$^2$, with a range from 12-123mm$^2$. Five are round section, four are plano-convex, two oval,
and one square. There is only one proximal (base) fragment: spindle-shaped. Three have longitudinal grooves (one double-sided). Three are decorated, the square section sagaie having a particularly complex set of geometric designs on all four faces—typical of the LCM. There are also two needle fragments—one with an “eye”. The frequency of grooved sagaies in both levels is noteworthy in relation to the large numbers of backed bladelets that were probably cutting edge inserts for such projectile points.

Level 505 also yielded several marine mollusk shells (all described in detail by Gutiérrez-Zugasti and Cuenca-Solana in this issue), notably many Antalis (Dentalium) tubes, a doubly perforated Trivia, a doubly perforated Nassa, a possibly perforated Littorina and three other perforated shell fragments, plus a scallop shell fragment—all testify to shoreline visits and/or exchanges with other bands living along the coast. All are more or less “normal” finds in LCM occupation layers in El Mirón.

5. Discussion and Conclusions

Lithic and osseous artifacts recovered from El Mirón Level 504 reflect variation typical of Lower Magdalenian archaeological sites in the Vasco-Cantabrian region. The relationship of these industries to the human remains found in the level—as “offerings”—remains problematic, though comparison of Levels 504 and 505 offers convincing evidence for fundamentally little disturbance of lithic concentrations in squares X/Y6 and 5, south of the burial per se. The osseous industry is highly fragmentary and poor in needles and perforated items; though small, the assemblage is similar in composition to those that have been found in non-ritual (i.e., residential) contexts of this age in El Mirón. The industry is composed mainly of broken antler points—some decorated—that reflect a very important LCM economic activity, i.e., hunting. These materials do not distinguish
themselves from “normal”, discarded LCM assemblages or from the underlying materials in Level 505 either quantitatively or stylistically and thus do not warrant classification as specific grave goods.

The lithic artifacts in Level 504, in addition to being significantly concentrated south of the human remains—albeit within this physically confined area at the vestibule rear—constitute an assemblage whose debris and tools uniformly indicate early-stage lithic reduction focused on flake and blade removals that prepared cores for late-stage bladelet production. The bladelet products relate directly to the abundance in bladelet tool industries found in this context. The spatial and artifact continuity of the lithic concentration with that of Level 505—which it echoes in nearly all aspects—suggests that despite any cultural and natural taphonomic processes affecting the area (human/animal digging, rodent burrowing, etc.), the assemblage has a great degree of integrity and is distinctive in its wealth of bladelet tools and debris. Finally, the rich assemblage of lithic tools from Level 504 reflects variation typical of the LCM—as indicated by comparisons to other dated contexts from the Mirón vestibule—further evidence that the artifacts deposited with the human remains in the Mirón rear vestibule are consistent with LCM economic activities rather than with ritual placement.

Despite the fact that the Level 504 artifact assemblages testify to economic activities typical of other LCM sites (e.g., El Juyo, Altamira), and other samples within the Mirón vestibule, the depositional context and variegated sediments—collectively defined by ochre staining—indicate that lithic and osseous materials may have been temporally and/or spatially displaced within the deposit as the human remains were buried and covered over with “back-dirt” some 19,000 years ago. Interpreted together,
the lithic and osseous materials recovered from Level 504 reveal an artifact-dense, functionally specialized LCM occupation, accompanied by a human burial at the rear of the El Mirón vestibule. These finds, coupled with extraordinary Lower Magdalenian pieces recovered from the outer vestibule Level 17—an engraved scapulae and atlatl hook (see Straus and González Morales 2009)—demonstrate the importance of this cave as a montane, residential location whose entire vestibule area was used for a wide range of human activities during the late Last Glacial (Oldest Dryas) period.

Acknowledgements

Excavations of the human burial in El Mirón cave, authorized and partly funded by the Government of Cantabria, were also financed by the L.S.B. Leakey Foundation and the UNM Fund for Stone Age Research (principal donors: Jean and Ray Auel). US National Science Foundation Doctoral Dissertation Improvement Grant #1318485 funded a portion of Fontes’ lithic analyses. Straus did the osseous artifact analysis.
## Table 1. El Mirón Levels 504 and 505 Lithic Debris Types, Counts, and Percentages.

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<th>Debris Type</th>
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<th>Percentage of Debris &gt;1cm</th>
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<td>Level 505</td>
<td>Level 504 (n=5690)</td>
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<td><strong>17,982</strong></td>
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Table 2. Tool Types in Four Contexts from El Mirón Cave. Tool types were made with respect to the de Sonneville Bordes and Perrot (1954, 1955, 1956a, 1956b) Upper Paleolithic tool typology (tool number is listed parenthetically). Tool types by excavation area are presented as counts; tool groups by area are presented as percentages of the total number of tools summarized in the upper portion of this table. El Mirón level 312 data are from Straus and González Morales (2008) and level 15 data are from preliminary analyses conducted by Fontes et al. (2012).

<table>
<thead>
<tr>
<th>Tool Type (counts)</th>
<th>Level 504 Burial</th>
<th>Level 505 Sub-burial</th>
<th>Level 312 Mid-vestibule</th>
<th>Level 15 “Cabin”</th>
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<td>2</td>
<td>7</td>
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<td>(3) Double endscraper</td>
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<td>--</td>
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<td>(5) Endscraper on a retouched flake/blade</td>
<td>--</td>
<td>--</td>
<td>1</td>
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<tr>
<td>(8) Endscraper on flake</td>
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<td>5</td>
<td>10</td>
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<tr>
<td>(9) Circular endscraper</td>
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<td>--</td>
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<td>3</td>
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<tr>
<td>(12) Atypical carinated endscraper</td>
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<tr>
<td>(13) Thick nosed endscraper</td>
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<td>(14) Flat nosed/shouldered endscraper</td>
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<td>3</td>
<td>4</td>
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<td>(15) Core endscraper</td>
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<td>51</td>
<td>10</td>
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<td>(17) Endscaper-burin</td>
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<td>(18) Endscraper-truncated piece</td>
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<td>(21) Perforator-endscraper</td>
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<td>(28) Slanted dihedral burin</td>
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<td>(29) Angle dihedral burin</td>
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<td>(30) Angle on break burin</td>
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<tr>
<td>(31) Multiple dihedral burin</td>
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<td>--</td>
<td>1</td>
</tr>
<tr>
<td>(33) Parrot beak burin</td>
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<td>--</td>
<td>1</td>
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<td>(34) Burin on straight retouched truncation</td>
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<td>--</td>
<td>2</td>
<td>1</td>
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<tr>
<td>(35) Burin on oblique retouched truncation</td>
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<td>(43) Core burin</td>
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<td>(48) Gravette point</td>
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<td>(61) Oblique truncated piece</td>
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<td>(63) Convex truncated piece</td>
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Table 2 (con’t)

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<tr>
<th>Tool Type (counts)</th>
<th>Level 504 Burial</th>
<th>Level 505 Sub-burial</th>
<th>Level 312 Mid-vestibule</th>
<th>Level 15 “Cabin”</th>
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<td>(64) Bitruncated piece</td>
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<td><strong>969</strong></td>
<td><strong>365</strong></td>
<td><strong>579</strong></td>
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<tr>
<th>Tool Groups (%)</th>
<th>Level 504</th>
<th>Level 505</th>
<th>Level 312</th>
<th>Level 15</th>
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<tr>
<td>Endscrapers</td>
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<td>0.3</td>
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<tr>
<td>Perforators</td>
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<td>1.4</td>
<td>3.1</td>
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<td>Burins</td>
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<td>2.7</td>
<td>2.9</td>
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<tr>
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<tr>
<td>Various Pieces</td>
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<td>Splintered Pieces</td>
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<td>5.4</td>
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Table 3. Percentages of Raw Material Types from El Mirón Level 504, by Artifact Type. Angular chunks are included in lithic debitage.

<table>
<thead>
<tr>
<th>Raw Material Group</th>
<th>Cores</th>
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<th>Tools</th>
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<tr>
<td></td>
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<td>Level 505</td>
<td>Level 504</td>
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<tr>
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<td>Quartzite</td>
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<td>Quartz and Calcite</td>
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<td>Mudstone</td>
<td>--</td>
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<tr>
<td>Limestone</td>
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<tr>
<td>Unidentified Stone</td>
<td>--</td>
<td>12.1</td>
<td>0.2</td>
</tr>
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</table>
Chapter 4:
Lithic Raw Material Conveyance and Hunter-Gatherer Mobility during the Lower Magdalenian in Cantabria, Spain

The manuscript presented in this chapter was authored by Lisa M. Fontes, Lawrence Guy Straus, and Manuel R. González Morales and is currently in press by *Quaternary International*. Fontes wrote the article and has included Straus and González Morales as co-authors because she used data from El Mirón Level 504 in the analysis. Straus provided productive comments on the first draft of the manuscript.

1. Introduction

Ethnographic studies of hunter-gatherers show that these groups’ organizational strategies are strongly tied to how key resources, whether fixed or seasonally variable, are spatially structured on their landscapes (Bamforth 1986, 1991; Binford 1978, 1980; Gould 1980; Jones et al. 2003; Kelly 2007; Kuhn 1991; Rensink 1995; Rensink et al. 1991). Hunter-gatherer mobility is spatially continuous, characterized by residential and/or logistical moves related to these resources (Binford 1980). Mobility and subsistence activities directly impacted the structure of the archaeological remains found today (Binford 1979, 1980; Kelly 2007; Rensink 1995; Rensink et al. 1991). Lithic technology is ideally suited for landscape-level human behavioral reconstructions because it is reductive: every activity that required stone tool modification (raw material preparation, manufacture, rejuvenation, etc.) has an archaeological trace that differs in character based on the point at which each activity occurred within a reduction sequence (Ahler 1989; Andrefsky 2009; Beck et al. 2002; Shott 1986, 2004). Additionally, lithic raw materials are expected to decrease in quantity through use as they are transported further from their source outcrops (Bamforth 1986). This paper assesses hunter-gatherer
landscape use during the Lower Magdalenian period by comparing lithic raw materials and evaluating their reduction stages, using samples recovered from four significant, multi-occupation, Cantabrian sites: Altamira (Freeman and González Echegaray 2001), El Juyo (Barandiarán et al. 1985), El Mirón (Straus et al. 2015), and El Rascaño (González Echegaray and Barandiarán 1981). In this analysis we argue that groups who occupied Cantabria during the Late Last Glacial utilized a large territory, conveyed raw materials between sites as they circulated within their habitual territories, and shifted environmental catchment zones as required by circumstances.

2. The Lower Cantabrian Magdalenian

The Lower Magdalenian period (c.16-14,000 uncal. years BP) in Cantabrian Spain was characterized by a cold, relatively dry climate and a largely treeless landscape (dotted with pines, junipers, and the occasional birch) with a combination of herbaceous, heath steppe, and tundra vegetation (Iriarte et al. 2015; Pokines 2000). Researchers studying the Lower Magdalenian generally agree that the archaeological culture was created by numerous, interacting local bands that together formed several distinctive regional groups whose territories were loosely defined by ecological zones (e.g., Vasco-Cantabria, the Pyrenees, southwest France, the upper Ebro River basin) and who interacted intermittently (Conkey 1980; González Morales and Straus 2009; Straus 2013). The Lower Cantabrian Magdalenian (LCM) is a unique Magdalenian cultural entity localized within ten river valleys in Cantabria and eastern Asturias provinces, within Vasco-Cantabrian north-coastal Spain. Its materials are striking (so much so that an early prehistorian, J. Carballo, argued that it was as distinct regional culture, and proposed naming it “Altamiran”, after the first site where it was found, Altamira, in Sanz de
Sautuola’s 1876-79 excavations), and include presence of so-called nucleiform endscrapers and backed bladelets, quadrangular-section antler *sagai*es with “tectiform” engravings, and red deer scapulae with striated engravings of (especially) red deer hinds and other ungulates (González Morales and Straus 2009; González Morales et al. 2007; Straus 1992, 2005, 2013; Utrilla 1981). Striated engravings have also been found underlying the polychrome bison paintings in Altamira and at other LCM sites (González Sainz 2005). The LCM also boasts astoundingly rich residential sites with dense palimpsest deposits that contained the aforementioned portable art, hearths, fire-cracked rocks, and spatially delimited activity areas that together suggest frequently occurring, structured occupations during which local resources (ibex in montane areas; red deer, fish, and shellfish on the coastal plain) were intensively exploited (Marín Arroyo 2009; Nakazawa et al. 2009; Straus 1992, 2005, 2013; Utrilla 1981). Archaeologists hypothesize that LCM bands moved among these mostly coastal residential hubs (e.g. Altamira, El Juyo), perhaps using specialized, logistical satellite camps (e.g. El Rascaño) to pursue additional comestible resources not available in littoral areas (ibex) (Altuna 1972; Straus 1986, 1987, 1992, 2013; Straus and Clark 1986; Straus and González Morales 2012b; Utrilla 1981). Together these features demonstrate that LCM groups formed a unique cultural entity within the Magdalenian interval, and one that is artistically, archaeologically, temporally, environmentally, and geographically well-defined (González Echegaray 1960; González Morales and Straus 2009; Straus 2013). Consequently, the LCM is an ideal case study with which to explore how mobility and other human behaviors (whether social, economic, etc.) intersected during the Late Last Glacial period.
3. Archaeopetrography in Vasco-Cantabria

Archaeopetrography is still an emerging research field in the Vasco-Cantabrian region. Only a handful of studies have characterized the lithic raw materials that outcrop in the province (see Straus et al. 1986; Bernaldo de Quirós and Cabrera 1996; González Sainz 1992; Rissetto 2009; Sarabia 1990a, 1990b). A. Tarriño (and his students at the Universidad del País Vasco) currently lead this research, having recently characterized major flint outcrops in northern Spain and southwest France (Tarriño et al. 2014). The flints Tarriño et al. (2014) documented are those chiefly used in this paper to reconstruct Last Glacial mobility, including:

(1) Barrika/Kurtzia flysch (Cenomanian-Santonian, Upper Cretaceous), a visually distinct, fine-grained grey flint that outcrops in a megabreccia along the Vizcaya coastline near Bilbao and Plentzia (Fig. 1), and has been identified in archaeological sites throughout the Vasco-Cantabrian region (Corchón et al. 2007; Tarriño 2006, 2012; Tarriño et al. 2013, 2014);

(2) Bidache flysch (Campanian, Upper Cretaceous), which outcrops between the French coast at Biarritz and Bidache on the Gaves Réunis (Pyrénées-Atlantiques) (Fig. 1; Normand 2002). This flint has been identified in prehistoric lithic assemblages throughout Vasco-Cantabria, its key feature being parallel turbidic laminations that are particularly evident when it is patinated (Corchón et al. 2007; Tarriño 2012; Tarriño et al. 2013, 2014);

(3) Cabo Mayor flint, (Late Cretaceous), a coarse-grained, greyish flint that outcrops on the coast just west of the city of Santander, Spain, and is infrequently identified in Cantabrian lithic assemblages (Fig. 1; Rissetto 2009);
Fig. 1. Locations of Lower Cantabrian Magdalenian sites and Lithic Outcrops discussed in the text.

Lower Magdalenian sites are abbreviated as follows: Altamira (A), El Juyo (J), El Mirón (M), and El Rascaño (R); this shorthand is used all subsequent figures. Raw material outcrops are numbered as follows: (1) Cabo Mayor; (2) Llaranza; (3) Sonabia flysch; (4) Barrika flysch; (5) Treviño; (6) Urbasa; (7) Bidache flysch; and (8) Chalosse. Raw material locations are approximate. Some additional coastal flysch outcrops may now be submerged due to sea level rise.

(4) Chalosse flint (Upper Cretaceous), which outcrops in a marine carbonate platform in southern Landes, France (Fig. 1; Tarriño et al. 2014). This flint is typically translucent in color, ranging from greyish to blackish. When patinated, the flint acquires a distinct, zoned, yellowish-white color. Chalosse flint has abundant bioclastic inclusions, including Lepidorbitoides sp., a macro-foraminifer that has led archaeologists to classify the raw material as a super-tracer flint that they can easily identify and use to reconstruct prehistoric territories and networks (Chalard et al. 2010; Tarriño et al. 2014). This material has been identified in sites throughout Vasco-Cantabria (Corchón et al. 2007; Tarriño 2012; Tarriño et al. 2013, 2014);

(5) Llaranza flint (Late Cretaceous), which outcrops along the coast east of the Santander Bay in Cantabria, Spain (Fig. 1). It is a very translucent flint that is variable in color, typically ranging from clear-white to yellowish-orange. Llaranza flint has been identified in Cantabrian Lower and Upper Magdalenian assemblages (Rissetto 2012);
(6) Sonabia flysch (Early Cretaceous), which outcrops on the coast near Laredo, eastern Cantabria, Spain (Fig. 1), and is recognizable by its dark blue-grey to whitish grey color and fine grain size. It has been identified in Cantabrian Lower and Upper Magdalenian assemblages (Rissetto 2012);

(7) Treviño flint (Miocene), which outcrops in the Miranda-Treviño Depression (in an enclave of Burgos province within southern Álava, Spain; Fig. 1) (Tarriño et al. 2014). This flint is extremely fine-grained and brownish in color, and occurs in almost all archaeological sites in Vasco-Cantabria that have been the subject of archaeopetrographic studies (see examples in: Corchón et al. 2007; Tarriño 2000, 2012; Tarriño and Aguirre 1997; Tarriño et al. 2014). Due to its ubiquity and distinct visual characteristics, Treviño flint is one of the most important tracer flints—along with Chalosse, Bidache flysch, and Urbasa flints—in the Vasco-Cantabrian and western Pyrenean regions (Tarriño et al. 2014);

(8) Urbasa flint (Paleocene), outcrops in a carbonate marine platform that is exposed in the karstic formations of the Sierra de Urbasa, NW Navarra, Spain (Fig. 1; Tarriño et al. 2014). Intensively exploited in prehistory, Urbasa flint is another lithic tracer identifiable by macroforaminifera, echinoderms, and easily recognizable early stage microdolomitization (i.e., micro-crystals), that have led to its identification in archaeological assemblages over 300km from the outcrop in Cantabria (Corchón et al. 2007; Tarriño et al. 2013, 2014), as well as in the western Pyrenees (Tarriño 2006) and southern Aquitane (Tarriño and Normand 2002).

These flints form a visually distinct raw material sample and together compose a major portion of each lithic assemblage examined here. It is worth noting that the Treviño and
Urbasa outcrops are located south of the Cantabrian Cordillera, which, however, has its lowest passes in the Basque Country sector.

4. The Sampled Sites

Altamira cave is located in Santillana del Mar, Cantabria, 65 m a.s.l. and approximately 10 km from the Oldest Dryas coastline (Fig. 1; Freeman and González Echegaray 2001). The site is located on the rolling coastal plain near the Río Saja, with easy access to the many resources of the Ice Age shore, as well as the hills and valleys around the site in an open parkland environment (Freeman and González Echegaray 2001). M. Sanz de Sautuola (1880) discovered human occupations and parietal art in Altamira in the 1870s and the site was subsequently excavated by H. Alcalde del Río (1906) and later by another team led by H. Obermaier (Breuil and Obermaier 1935). L.G. Freeman and J. González Echegaray conducted an excavation of an ~4m² area of the cave in 1980-81 that is the subject of this analysis. They recovered LCM occupational residues, dated to 15,910±230 uncal. BP (I-12012), from pit structures in a small portion of the Altamira vestibule (González Echegaray 1988). Faunal materials included red deer, fish, and shellfish remains (*Patella* and *Littorina*) that indicated fall through spring occupations in the cave (Freeman 1988; Freeman and González Echegaray 2001). Additionally, the site is known for its rich collection of osseous artifacts and portable artworks recovered from even the earliest investigations in the cave (Breuil and Obermaier 1912, 1913), which have contributed to archaeological interpretations of the site as a possible location for seasonal human aggregations (Conkey 1980). In addition to creating and/or exchanging portable art items, mates, and ideas, archaeologists have proposed that aggregated groups intensively pursued local resources—wild harvesting
red deer in herds, netting salmon as they migrated upriver to spawn—and then later divided themselves into smaller foraging groups who benefitted from the surplus created during large group hunts (Conkey 1980; Freeman 1973; Pokines 2001; Straus 1975-1976, 2013).

El Juyo cave, located in Igollo, Cantabria, is another large coastal zone site that contains a major LCM palimpsest with several occupation levels (Fig. 1; Barandiarán et al. 1985). The site is approximately 12 km from the Last Glacial coast and 60 m a.s.l., where nearby hills c. 100 m a.s.l. offer excellent views of the local terrain (Pokines 2001). The excavation unearthed several LCM levels, three of which are dated: Level 4 to 13,920±240 uncal. BP (I-10736), Level 6 to (no doubt erroneously) 11,400±300 uncal. BP (I-10737) and Level 7 to 14,440±180 uncal. BP (I-10738) (Barandiarán et al. 1985; Freeman et al. 1988). This analysis focused on Level 6, a 17m² area that is notable for a multi-chambered, stone-lined structure that included large quantities of worked and unworked bones. (Barandiarán et al. 1985; Klein et al. 1981, 1983; Pokines 2001). Faunal remains from the site indicate that both red deer and salmon were exploited en masse using what Freeman (1973) termed “wild harvesting” (see also Pokines 2001). Both direct evidence from fauna and indirect evidence from barn owls suggest that El Juyo was occupied from late autumn through late spring (Pokines 2001). Additionally, the site is known for its wealth of exceptionally small bladelet tools—termed “Juyo” bladelets—that were likely used in LCM composite projectiles (Barandiarán et al. 1985; González Echegaray and Freeman 2007).

El Mirón is a prominent cave located 255 m a.s.l. in Ramales de la Victoria, Cantabria, in the montane zone approximately 25-30 km inland from the Oldest Dryas...
coastline (Fig. 1; González Morales and Straus 2005; Straus and González Morales 2003, 2012a; Straus et al. 2008). The site is located above the Asón valley in a foothill range of the Cantabrian Cordillera, surrounded by ≥1000 m peaks, and above the confluence of two rivers with the Asón. The site is also located at the crossroads of two avenues of communication: east-west through central Cantabria via the 674 m Alisas Pass, and north-south from the coast to the meseta via 918 m Los Tornos Pass in the upper Asón valley (Straus et al. 2015). The El Mirón vestibule is capacious, overlooking the lower valley. L.G. Straus and M. R. González Morales have directed excavations in several areas of the site since 1996, including the outer vestibule “Cabin”, a mid-vestibule trench, and the rear vestibule “Corral” and human burial area at the southeast corner of the vestibule (González Morales and Straus 2009; Straus et al. 2008; Straus et al. 2015). The site has one of the best-dated Upper Paleolithic sequences in the Vasco-Cantabrian region (Straus and González Morales 2003, 2007, 2010). This analysis concerns only lithic artifacts from Level 504, located in the ~4m² burial area and containing the burial itself (Fontes et al. 2015), that two radiocarbon assays date to 15,460±40 uncal. BP (MAMS-14585) and 15,740±40 uncal. BP (UGAMS-7217) (Straus et al. 2015). El Mirón’s LCM occupants exploited red deer and ibex during winter and spring months (Marín Arroyo and Geiling 2015). The site has yielded very large quantities of lithic debris that demonstrate that bladelet production was a major activity in several areas of the site—including the burial area (Fontes et al. 2015; Straus et al. 2008).

Finally, the small El Rascaño cave is located in Mirones, Cantabria, 275 m a.s.l. and 32 km from the Last Glacial coastline, in an abrupt, montane landscape (Fig. 1; González Eccegaray and Barandiarán 1981). The 1974 excavations, conducted by I.
Barandiarán and J. González Echegaray, with the assistance of L.G. Straus and others, were localized in a small remnant area (~4m²) of intact deposits in the rear section of El Rascaño. The LCM occupation, dated to 15,988±193 uncal. BP (B.M. 1453), yielded faunal remains that indicate multi-seasonal site use and near-exclusive ibex exploitation on the surrounding, steep, rocky slopes (González Echegaray and Barandiarán 1981). The lithic assemblage includes high numbers of nucleiform endscrapers and few backed bladelets (similarly to Altamira’s lithic assemblage), both diagnostic components of LCM occupations (González Echegaray and Barandiarán 1981; Straus 1992; Utrilla 1981). Additionally, the osseous industry was manufactured *in situ*—all phases of *sagaie* manufacture are evident in the worked bone assemblage (Utrilla 1981). El Rascaño also yielded a striation-engraved red deer scapula, which, together with evidence from lithic and osseous industries, demonstrates that despite the cave’s small size and highly specialized hunting activity, occupations at the site were diverse in their character (González Echegaray and Barandiarán 1981; González Morales and Straus 2009; Utrilla 1981).

5. Methodology

Lithic samples were taken from Altamira Level 2 (n=3439), El Juyo Level 6 (n=3511), El Mirón Level 504 (n=6212) and El Rascaño Level 4/4B (n=2708) (Barandiarán et al. 1985; Fontes et al. 2015; Freeman and González Echegaray 2001; González Echegaray and Barandiarán 1981; Straus et al. 2015). These samples represent all lithic artifacts greater than one linear centimeter in size in each level/site. All lithic artifacts were analyzed individually and classified using a debris typology that distinguished: whole and fragmentary cortical and non-cortical flakes, bladelets (parallel
sited and <2 cm), and blades (>2 cm); chunks (angular debris); microburins and burin spall; platform renewal flakes; splintered pieces; uni-and bi-directional crested blades; and flake, pyramidal blade(let), prismatic blade(let), and mixed cores (modified from Straus et al. 2008). Additionally, a series of quantitative and qualitative attributes were recorded for each artifact, including:

(1) raw material type, which was determined using ad hoc reference collections made for each site to categorize the heterogeneous array of rocks identified in each assemblage. Each collection visually distinguished raw materials based on their: color (and any variations therein); homogeneity; grain size; texture; matte/sheen; opacity/translucence; patina; fracture mechanics (conchoidal, orthogonal, etc.); and cortex color/texture. These reference materials were then directly compared to each other and to two petrological reference collections to make geographic source attributions. The first archaeopetrographic reference collection used for this study was made by A. Tarriño (2012) for Aitzbitarte IV (Guipúzcoa—curated at the Centro de Custodia in San Sebastián), and includes specimens of Barrika/Kurtzia, Bidache, Chalosse, Treviño, and Urbasa flints (Fig. 1). J. Rissetto (2009), in association with the El Mirón Project, assembled the second collection (curated at the IIIPC, Universidad de Cantabria), which includes samples from Barrika, Cabo Mayor, Llaranza, and Sonabia flints (Fig. 1);

(2) artifact weight, to the nearest 0.1 gram;

(3) for whole debitage, dorsal cortex portion (modified from Andrefsky 2005 to consider four stages: absent; <⅓ exterior cortical surface; ⅓ to ⅔ cortical, and ⅔ to complete), and for all other artifacts, cortex presence or absence;

(4) for whole debitage, dorsal scar count (after Andrefsky 2005);
(5) artifact size, including length, width, and thickness to the nearest millimeter for whole debitage, and using a square centimeter size chart for all debitage; and,

(6) debitage fragmentation (proximal, mesial, distal, longitudinal, indeterminable, and whole).

Together, these variables provide information about LCM lithic manufacture and conveyance patterns at four sites in the Vasco-Cantabrian region.

5.1 Analytic Nodules and Reduction Sequences

Lithic artifacts were characterized as analytic nodules that were distinguished by visually distinct raw material types. A reduction stage (all, early, mid, late, or indeterminable) was assigned to each material type at each site based on the following criteria:

(1) presence of typological diagnostics created during each stage: primary decortication flakes or blade(lets) indicate early stage reduction; microburins, burin spall, crested blades, and platform renewal flakes demonstrate mid-stage reduction; and splintered pieces and cores signal late stage reduction;

(2) progression in lithic reduction based on a ten stage cortex/reduction continuum that combined characterizations of dorsal cortex and dorsal scar count, beginning with primary cortex without previous removals to intermediate phases with decreasing cortex and increasing numbers of removals, and ending with no cortex and three or more removals; and

(3) artifact size, where larger debitage were presumed to have been produced earlier in a continuous reduction sequence than their smaller counterparts.
Reduction stages were considered indeterminable if there was no diagnostic artifact present. Additionally, some raw materials were attributed an indeterminable stage due to their very small artifact sample sizes, which thus could not reliably be attributed to a reduction stage. Reduction stages were used to evaluate conveyance relationships among Cantabrian sites.

5.2 Assumptions and Mobility Modeling

It is well established that behavioral reality—especially as it relates to group movement—was much more complex than what data are evident from the archaeological record (Binford 1978, 1979, 1980; Gould 1980; Kelly 1992, 2007; Schiffer 1972; Shott 1986). Each analytic nodule identified at a Cantabrian site could represent single or several reduction events that used one or many manufacture techniques, on behalf of one or more hunter-gatherer groups. For example, Barrika toolstone was identified in all reduction stages at El Mirón cave. These artifacts could have resulted from a single occupation where whole cobbles were reduced, or from multiple occupations where only single reduction stages occurred. The analytic nodule merges this plausible behavioral variation into a single sequence and assumes that for every occupation at El Mirón, Barrika toolstone (from a major outcrop in western coastal Vizcaya near Bilbao) was reduced in all stages. The use of “time averaging” in this manner is a common element of Paleolithic archaeology, due in part to palimpsest formations (Bailey 1983, 2007). The analytic nodules represent patterned lithic raw material use in each cave that corresponded to regular, scheduled territorial exploitation (Straus 2013). Consequently, each sites’ place in a structured settlement-subistence system can be traced through these patterned residues (Binford 1980; Straus 1979, 1990, 1997, 2013; Straus and Clark 1986).
A second issue is each analytic nodule’s sample size. Each raw material is represented in different quantities in each assemblage, which could reflect landscape or behavioral variation: the toolstone’s abundance (i.e. outcrop size); territorial access to toolstone (proximity); manufacturing preferences (fracture mechanics and/or perceived/actual toolstone need); or the role of the material in the toolkit (i.e. primary or supplementary to the materials already on hand at the time it was procured), among other factors (Andrefsky 1994; Bamforth 1986; Bamforth and Bleed 1997; Beck et al. 2002). Rather than presuming how or why groups accessed particular stones, this analysis focuses on a behavioral common denominator: that the proportions of each raw material in an assemblage reflect the amount of that material that was in the hunter-gatherers’ toolkits when they occupied the site (i.e., if Treviño is 8% of the El Juyo lithic assemblage, it was also 8% of the mobile toolkit when groups resided at El Juyo). This assumption enables inter-site comparisons based on raw material portions.

An additional confounding factor is overall sample size: excavation sampling within each cave also could have influenced the relative proportions of analytic nodules in each assemblage. For example, in Altamira cave, the area Freeman and González Echegaray excavated is less than a tenth of the total area within the cave exposed by earlier campaigns (Alcalde del Río 1906; Breuil and Obermaier 1935; Conkey 1980; Freeman and González Echegaray 2001; Straus 1975-1976). Despite the behavioral possibility that many more raw material types than those already identified could have been reduced at Altamira in other parts of the vestibule, or even that other stages of reduction could have occurred for those materials that have been identified, it is assumed that the raw materials identified at Altamira would remain consistent—in proportion and
reduction stage—whether the sample size was 3,439 artifacts or 34,390. While this assumption is necessary to make inter-site comparisons and reconstruct Magdalenian lithic conveyance, the authors wish to note that Last Glacial behaviors were much more complex than what the archaeological record from palimpsest settings often reveals, particularly in terms of spatial organization. Archaeologists have recorded spatially complex Magdalenian sites in areas with exceptional preservation, including northern Spain (El Juyo, La Garma) and the Paris Basin (Etiolles, Pincevent, Verberie) (see Arias et al. 2011; Audouze and Enloe 1997; Barandiarán et al. 1985; Leroi-Gourhan and Brézillon 1972). Some samples used in this study come from small areas (Altamira, El Mirón, and El Rascaño) and/or spatially marginal zones (El Rascaño), which may have influenced the lithic-related activities that Magdalenian hunter-gatherers did in these spaces, and consequently, limit our interpretations of Magdalenian lithic conveyance. It is possible that if additional areas from each cave were analyzed and compared, that the interpretations presented in this paper could change (Fontes’ forthcoming analyses will specifically address this issue in El Mirón and El Juyo caves, where many other samples were excavated from larger areas and are available for analysis).

Finally, to reconstruct Magdalenian lithic conveyance (and by proxy, hunter-gatherer mobility), this study assumes that groups directly accessed raw materials from source outcrops, perhaps as part of an embedded procurement strategy, and then conveyed them through foraging territories (following Amick 1996; Binford 1979; Cowan 1999; Goodyear 1989; Jones et al. 2003, 2012; but see also Bamforth 2002; Elston and Zeanah 2002; and Madsen 2007). Based on raw material diversity, an LCM mobile toolkit contained artifacts of several lithic toolstones; presumably, each
component was gradually reduced through myriad tasks (with traces apparent in reduction stages at sites where those activities occurred), eventually losing its utility and being discarded, replaced by another raw material (Andrefsky 1994, 2009; Bamforth 1986; Beck et al. 2002; Shott 1986). This analysis assumes that each raw material was reduced in quantity within the mobile toolkit as groups moved further from its source outcrop, a concept commonly called “distance decay” (Bamforth 1986). Overall, the lithic conveyance relationships modeled here compound individual behaviors into patterned ones that enable reconstructions of long-term hunter-gatherer landscape use in Cantabria (Bailey 1983, 2007; Binford 1980; Straus 2013).

6. Results

6.1 Altamira Assemblage Summary

Altamira has 47 visually distinct raw materials in the studied assemblage. Twenty-three of those materials are “local” stones that were only identified at Altamira. These “local” stones include six quartzites, six unknown stones, and 11 flints that are collectively nearly a quarter of the Altamira lithic assemblage (Table 1). Six of these raw materials, four flints (F36, F48, F61, F63) and two quartzites (QZ17, QZ24), were identified in all stages of lithic reduction. Presumably, these raw materials were acquired near Altamira and reduced on site to meet immediate raw material needs and supplement the transported raw materials in the mobile toolkit. Five additional flints were identified in early (n=1; F53) and late stages (n=4; F10, F22, F62, F64). These flints were probably brought to Altamira after having been reduced in early and middle stages at other LCM sites or quarrying locations. All remaining “local” materials (n=8) had indeterminable reduction stages (Table 2). These eight toolstones are presumably conveyed materials that
were either part of mid-stage reduction sequences that only produced a few blanks, or otherwise were transported blanks created in reduction sequences that occurred elsewhere. Reduction stage variation in the Altamira assemblage indicates that raw material conveyance was an important component of LCM lithic economies: groups structured their raw material procurement to correspond to both their localized and long-term settlement-subsistence needs.

Twenty-four toolstones identified at Altamira had been conveyed among Cantabrian LCM sites; these materials represent the greatest portion of the raw material assemblage, 38.5%. Five of these materials have known geographic origins: Barrika, Llaranza, Sonabia, Treviño, and Urbasa (Fig. 1). Llaranza, the source outcrop closest to Altamira, only ~38 km northeast of the site on the present shore east of Santander, is the greatest portion of the cave’s assemblage (18.9%; Tables 1 and 3). The next most abundant source material is Sonabia (9%), a source ~63 linear km east of Altamira on the present shore in eastern Cantabria (Fig. 1). Artifacts manufactured using high-quality Barrika flysch, Urbasa, and Treviño (the latter two outcrops in the interior Basque region) are each under 5% of the Altamira assemblage; these outcrops are located far from Altamira cave (Table 3). Despite its proximity to Altamira (~28 km), flint from Cabo Mayor (on the edge of Santander city), of medium-quality, is absent in the assemblage; higher quality flints from Llaranza, Sonabia and Barrika may have been preferred Cantabrian outcrops. These materials may have been acquired and transported to the site as part of an embedded procurement strategy that brought groups along the Cantabrian coast. Raw materials that outcrop in extreme southwest France—Bidache and Chalosse—are absent from Altamira. If the site was used as an aggregation location for Magdalenian
groups (following Conkey 1980), there is no evidence that these high-quality raw materials were imported, reduced, or exchanged at Altamira. Indeed, if the cave was used for periodic aggregations, the lithic economy does not appear to have been supplemented by these activities.

6.2 El Juyo Assemblage Summary

The El Juyo assemblage has 44 visually distinct raw materials, 22 of which are “local” toolstones (7.8%; Table 1). All of the non-flint “local” materials (n=4) recovered from Level 6 were in indeterminate reduction stages (Table 2). Among the “local” flints with unknown geographic origin, only one material, F41, was reduced in all stages at the site; all others were in mid-late stage (n=3), late stage (n=5), or indeterminate stages (n=7). This demonstrates that most of the “local” toolstones from El Juyo Level 6 were transported to the site after having been initially reduced elsewhere. Finally, two local raw materials originate from known geographic outcrops: Cabo Mayor, located ~10 km northeast of the site; and Chalosse, located ~270 km east of El Juyo in southwest France. Artifacts manufactured from Cabo Mayor flint were in an indeterminate reduction stage, whereas those made using Chalosse were in late stage reduction (Table 2). Since Chalosse outcrops so far from El Juyo and it was not recovered in any of the three other sites, it is reasonable to hypothesize that this material arrived at El Juyo through inter-group exchanges. However, because the artifacts signal late-stage reduction and it seems unlikely that groups would exchange raw materials that lacked significant utility, this exchange may have occurred outside of Cantabria, perhaps when LCM groups accessed raw material outcrops in northwestern Navarra, which are much closer to French Magdalenian territories.
Twenty-two raw materials identified at El Juyo were conveyed among Cantabrian sites. Five of these toolstones come from known outcrops: Sonabia and Barrika, located ~45 and ~73 km east of El Juyo, respectively; Llaranza, which outcrops ~18 km northeast of the site; and Treviño and Urbasa, which outcrop over 100 km to the southeast of the cave (Fig. 1; Table 3). The materials most abundant in the El Juyo assemblage are Sonabia (37.4%) and Barrika (11.8%), despite the fact that these outcrops are much further from the cave than Llaranza (only 2.8% of the artifacts). Treviño and Urbasa flints are also more abundant than Llaranza (8.6% and 5.3% respectively) (Table 1). All of the known (and abundant) flints identified in the El Juyo assemblage come from outcrops located east of the site, suggesting that the cave was occupied following westward movement within a large territory that extended into western Navarra. The proportions of geographically known raw materials identified at El Juyo demonstrate that toolstones could have been directly accessed by LCM groups as part of an embedded procurement strategy, and reduced gradually as groups traversed the region.

6.3 El Mirón Assemblage Summary

El Mirón has 43 raw materials identified in its assemblage, 24 of which are “local” materials (11% overall). El Mirón has the most diverse “local” raw materials of the four Cantabrian sites; its assemblage includes flints, quartzites, mudstones, quartzes/calcites, and other materials. Artifacts manufactured in the three mudstones and the quartz signal indeterminate stage reduction. The other materials, O5 and O6, indicate early and indeterminate stage reduction, respectively. The assemblage has three quartzites, one in each early, mid, and indeterminate reduction stages (Table 2). Lithics manufactured in the 14 geographically unknown flints indicate varying reduction stages: all (n=3), early
(n=2), early to mid (n=2), mid (n=1), late (n=3), and indeterminate (n=3). This reduction stage diversity demonstrates that Last Glacial hunter-gatherer groups managed raw materials within the mobile toolkit following their procurement and supplemented conveyed toolstones with local materials that they reduced in all stages at El Mirón. Additionally, even lower quality raw materials, like quartzites, signal this same pattern, testifying their importance to LCM economic strategies. Finally, one “local” flint has a known origin, Bidache flysch, which outcrops ~190 km east of El Mirón in southern France (Table 3). Similarly to the Chalosse recovered from El Juyo Level 6, the artifacts manufactured at El Mirón using Bidache flysch (0.8% of the assemblage) point to mid-late stage reduction. LCM groups probably acquired Bidache flysch through inter-group exchange, and, due to its late stage reduction representation, this exchange may have occurred outside of Cantabria.

Nineteen raw materials identified in El Mirón Level 504 were conveyed among other Cantabrian sites. Five of these materials originate from geographically known outcrops: Barrika, 41.8% of the assemblage, located ~40 linear km northeast of El Mirón; Llaranza (26.6%), ~32 km northwest of the cave; Sonabia (3.2%), ~20 km to the northeast; and Treviño and Urbasa, both <1% of the assemblage, located ~80 km and ~112 km southeast of the site, respectively (Tables 1 and 3). Assuming that raw materials were acquired through an embedded procurement strategy, the El Mirón assemblage signals two mobility patterns: one moving eastward, perhaps following exploitation of environments near the western LCM sites in Asturias, in which Llaranza flysch was procured and transported to the cave; and a second westward progression, following use of the eastern LCM territory around Treviño and Urbasa, and subsequent toolstone
acquisition at the Barrika outcrop. Were either Llaranza or Barrika directly procured from a base camp at El Mirón, groups would have had to make very costly ~60-100 km round trips in either direction in order to procure a combined 68% of their toolkit; archaeologists have hypothesized that hunter-gatherer groups would avoid incurring these kinds of expenses (time, energy, etc.) in procuring lithic toolstones (Gould 1980). Finally, despite their small portions, the presence of Treviño and Urbasa flints in the El Mirón assemblage demonstrates that the cave’s LCM occupants utilized the same territory as those groups who resided at Altamira and El Juyo, or, if the materials were imported, groups utilized similar social contacts.

6.4 El Rascaño Assemblage Summary

El Rascaño has 35 raw materials in the assemblage, 15 of which were “local” toolstones (7.8%) (Table 1). None of the “local” materials shows all stages of lithic reduction. There are: two unknown stones in indeterminate stages; four quartzites, two in indeterminate stages and two in late stage reduction; and nine flints that indicate early and late stage (n=1), mid stage (n=1), mid-late stage (n=1), late stage (n=3), and indeterminate stage (n=3) reduction (Table 2). These stage attributions suggest that “local” materials were conveyed to El Rascaño, with early reduction stages having occurred elsewhere. This supports González Echegaray and Barandiarán’s (1981) assertion that occupations at El Rascaño were short and focused: unlike the other Cantabrian sites, the El Rascaño the assemblage was likely formed through occupations that were entirely provisioned by the mobile toolkit and not supplemented by “local” raw materials that were reduced in all stages at the site.
Twenty raw materials identified in the El Rascaño assemblage were conveyed toolstones, five of which were geographically known, including Barrika, Llaranza, Sonabia, Treviño, and Urbasa. Sonabia, located ~36 km northeast of the cave, comprises the greatest portion of the El Rascaño assemblage, 41.3% (Table 1). Llaranza, ~30 km north of El Rascaño, is the next most abundant raw material, only 7.7% of the assemblage. Despite being a roughly equivalent distance from the cave (~35 km), Cabo Mayor was not identified in the El Rascaño assemblage. Barrika flysch, whose outcrop is located ~60 km to the northeast of the site, is also ~7% of the lithic assemblage. Barrika, Sonabia, and Llaranza outcrops may all have been accessed as groups made westward movements along the Cantabrian coast. Finally, both Treviño and Urbasa each compose ~3% of the assemblage; they are located ~90 km and ~130 km southeast of El Rascaño cave, respectively. The raw materials identified in the El Rascaño assemblage demonstrate that this cave was occupied as part of an economic system that also included Altamira, El Juyo, and El Mirón caves, and extended from Cantabria into western Navarra.

6.5 Inter-site Conveyance within Cantabria

Raw materials that were transported between Cantabrian sites formed significant portions of the Altamira (38.5%), El Juyo (26.2%), El Mirón (15.7%) and El Rascaño (29.5%) assemblages. Lithic artifacts manufactured in these materials provide information about LCM mobile toolkit organization and raw material circulation in Cantabria.

6.5.1 Mobile Toolkit Organization

Thirty-three visually distinct toolstones were conveyed among the Cantabrian sites: 17 raw materials were transported between two locations, five among three
locations, and nine among four locations. Lithic reduction stages for conveyed materials can be summarized as follows: all stages (n=28 occurrences); early stage (n=3); early-mid stages (n=2); mid stage (n=2); mid-late stage (n=10); late stage (n=17); and indeterminate stages (n=23) (Table 4). Raw materials reduced in all stages indicate that LCM groups transported whole cobbles through the region. All stage reduction was as prevalent as mid and late reduction stages, demonstrating that both whole nuclei and partially reduced cores were components of mobile toolkits. However, early reduction stages are comparatively rare. These occurrences—all in lower quality raw materials: limestone, mudstone, unidentified stone, and quartzite—may signal cobble testing at sites following local material procurement, which LCM flintknappers could have used to evaluate whether or not cobbles were of sufficient quality/utility to transport to other locations. Every raw material signals advances in reduction stage as its assemblage weight decreases, with exceptions of QZ1, QZ23, M3, U6, F29, Treviño, and QC1 (Table 4). There are several possible explanations for these inconsistencies. First, for those materials identified in an indeterminate reduction stage in at least one assemblage (QZ1, QZ23, M3, and QC1), it is possible that these materials were created in mid-stage reduction that did not produce a diagnostic artifact. A second possible explanation is that LCM groups produced these artifacts through a strategic raw material management process: the debris may be the result of flintknapping aimed at producing only a few blanks for specific tasks. Occupation span is an additional factor: if groups resided at a site for a short period of time, their raw material needs may have been less, consequently, flintknappers may have reduced and discarded smaller quantities of stone, conserving the most valuable nodules for reduction at sites with longer residencies (e.g., Treviño).
Overall, the correlation between reduction progression and weight decrease demonstrates that distance decay is a reasonable proxy for reconstruction of raw material circulation. Additionally, the reduction stage diversity among conveyed lithic raw materials provides insight into LCM mobile toolkit organizational strategies. Each toolstone was managed within the toolkit, even those reduced in all stages at LCM sites, which could have supplemented the mobile toolkit at the site nearest to the source outcrop and then provided surplus that was transported to other locations. This demonstrates that these tool frameworks were anticipatory, prepared to provision LCM group activities as they traversed a large territory and completed their daily tasks.

6.5.2 Raw Material Circulation

Raw material circulation in Cantabria was evaluated using distance-decay patterns derived from differences in raw material weights in each assemblage. For example, F50 is identified in all reduction stages at El Rascaño, where the analytic nodule weighs 533.8 g. At El Juyo, F50 weighs only 35.6 g and signals mid-late stage reduction. Thus, F50’s distance decay pattern demonstrates raw material conveyance—and by proxy, hunter-gatherer movement—from El Rascaño to El Juyo (Table 4). The same process was used to elucidate movements among three and four sites, for example, F66 points to group movement(s) from El Juyo (all stage reduction, 471.6 g) to Altamira (all stage reduction, 86.3 g), and then El Rascaño (late stage reduction, 52.5 g). Distance decay patterns can indicate inter-site relationships and localized, patterned hunter-gatherer group movements.

There are six major bidirectional single conveyance trajectories between Cantabrian sites: Altamira-El Juyo; Altamira-El Mirón; Altamira-El Rascaño; El Juyo-El
Mirón; El Juyo-El Rascaño; and El Mirón-El Rascaño. Twelve toolstones signal bidirectional movements between Altamira and El Rascaño, a ~40 km journey. Ten raw materials demonstrate toolstone conveyance between Altamira and El Juyo, two sites ~20 km from each other, and between El Mirón and El Rascaño, also ~20 km apart (Table 5). Eight raw materials were conveyed between El Juyo and El Rascaño (~30 km apart) and between El Juyo and El Mirón (~40 km apart). Finally, only six raw materials were conveyed on the trajectory from Altamira to El Mirón, a ~57 km journey. Altamira-El Rascaño, Altamira-El Juyo, and El Mirón-El Rascaño are the three conveyance trajectories with the greatest variety of transported raw materials, which may indicate that these pathways were traveled more often than the others, perhaps due to their proximity, which would have reduced the costs of group movement (in the case of Altamira-El Juyo and El Mirón-El Rascaño; Kelly 1992), or caused by a need to change environmental zones (coastal Altamira to montane El Rascaño). El Juyo-El Mirón and El Juyo-El Rascaño trajectories also involved movement between environmental zones, and would have been journeys similar in length as that of Altamira to El Rascaño. A desire to minimize movement costs also explains why so few materials (n=6) were transported on the Altamira-El Mirón trajectory: the two sites are a several days’ journey from each other.

Single conveyance trajectories can also be evaluated in terms of directionality—whether groups moved eastward or westward—as part of systemic settlement progressions through the LCM territory. There are six eastwardly inter-site trajectories: Altamira-El Juyo, Altamira-El Mirón, Altamira-El Rascaño, El Juyo-El Mirón, El Juyo-El Rascaño, and El Rascaño-El Mirón. Thirty raw materials were conveyed along these
trajectories (Table 5). There are also six westward conveyance trajectories, evidenced by 24 raw materials: El Juyo-Altamira, El Mirón-Altamira, El Mirón-El Juyo, El Mirón-El Rascaño, El Rascaño-Altamira, and El Rascaño-El Juyo (Table 5). Despite the fact that most of the geographically known raw materials originate from eastern outcrops and demonstrate westward movement, the overall sample indicates that toolstone conveyance—and by proxy, LCM hunter-gatherer mobility—was commensurate in each direction. Thus, lithic raw materials not only demonstrate inter-site mobility patterns that may have been impacted by shifting local environmental patchworks, but also by fluctuating annual ranges that would have brought groups into local or sub-regional territories (i.e., the Nalón valley in Asturias or the Asón valley in Cantabria) within the much larger LCM territory. Lithic raw materials demonstrate that LCM groups would have balanced multiple mobility scales—site-catchment zones, sub-regional territories, annual ranges, and inter-territorial networks—as they organized their economic strategies.

While there are many instances of single conveyance relationships between sites (one for every material identified at two sites, two for each toolstone at three sites, etc.), there are fewer raw materials that have been identified as part of three or four site multiple conveyance pathways (Table 5). Three multiple conveyance pathways are indicated by three raw materials each: Altamira-El Rascaño-El Mirón (a ~60 km trajectory); El Juyo-Altamira-El Rascano (~60 km); and El Juyo-El Rascaño-Altamira (~70 km). All of these pathways would have incurred similar movement costs and would have brought groups through coastal and montane environmental zones. Two of these trajectories would have carried groups eastward (Altamira-El Rascaño-El Mirón and El Juyo-Altamira-El Rascaño), while the third signals a circular settlement pattern. Two
multiple conveyance trajectories are signaled by two raw materials each: El Mirón-El Rascaño-Altamira (westward movement) and El Rascaño-El Mirón-El Juyo (semi-circular movement). Again, along these trajectories LCM groups would have incurred ~60 km movement costs and shifted environmental zones. All other multiple conveyance pathways are evidenced by single raw materials (Table 5). Multiple conveyance pathways reinforce that LCM groups organized short moves between adjacent sites in order to exploit the diverse environmental patches within Cantabrian Spain while minimizing costs of group movement (Kelly 1992).

There are nine raw materials that were recovered at all four sites, which inform nine multi-site conveyance models (Figs. 2-4). Barrika, Llaranza, and Sonabia were identified in all reduction stages at Altamira, El Juyo, El Mirón, and El Rascaño. Barrika toolstone testifies to a conveyance trajectory from the outcrop to El Mirón (2271.3 g), El Juyo (1146.8 g), El Rascaño (503.7 g), and finally, Altamira (368.4 g) (Table 4; Fig. 2). Barrika is the only toolstone that shows this multi-site conveyance pathway, a ~110 km trajectory. Sonabia toolstone indicates a multi-site conveyance pathway beginning at El Juyo (3623.4 g), then to El Rascaño (2856.8 g), Altamira (729.5 g) and El Mirón (173.7 g). This raw material was also carried on a unique trajectory, and at 127 km, it is also one of the longest conveyance trajectories modeled using these samples. Llaranza toolstone was conveyed on a ~107 km trajectory beginning at Altamira (1537 g), then to El Mirón (1447.3 g), El Rascaño (530 g) and El Juyo (267.4 g). That Altamira and El Mirón have nearly equal portions of this material could be related to LCM groups using embedded procurement strategies that brought them to source outcrops as part of their eastward movements through Cantabria. With the exception of a single move from El Mirón to El
Fig. 2. Models of Local Raw Material Conveyance from Coastal Outcrops

Transport pathways for Barrika, Llaranza, and Sonabia through Lower Cantabrian Magdalenian sites. Conveyance order was based on progressive weight decrease in assemblages, where the site with the greatest amount of raw material was visited first and the least occupied last. Lines are heuristic and not intended to represent exact routes travelled by Last Glacial groups.
Rascaño evidenced by the Llaranza analytic nodule, every single conveyance pathway indicated by Barrika, Llaranza, and Sonabia toolstones involved a shift to a different environmental zone. Additionally, these three analytic nodules signal all stages of lithic reduction, underscoring that whole cobbles were important components of LCM mobile toolkits.

![Models of Local Raw Material Conveyance from Treviño and Urbasa Outcrops](image)

**Fig. 3.** Models of Local Raw Material Conveyance from Treviño and Urbasa Outcrops

Transport pathways for Treviño and Urbasa through Lower Cantabrian Magdalenian sites. Progressive weight decrease determined conveyance order, as described in the Fig. 2 caption. Alternately, if reduction stage is considered in addition to weight, Treviño can be modeled from El Juyo to El Mirón, Altamira, and then El Rascaño. However, the El Rascaño assemblage has four times as much Treviño as samples from El Mirón and Altamira, which is why the weight-based model is presented here. Lines drawn between sites are models that do not represent exact routes travelled by Last Glacial groups.
Treviño flint was identified in all reduction stages at El Juyo, in late stage reduction at El Rascaño, and in mid-late reduction stages at Altamira and El Mirón, signaling a 107 km conveyance pathway within Cantabria. Urbasa flint was identified in all reduction stages at both Altamira and El Juyo, in mid stage at El Mirón, and mid-late at El Rascaño, testifying to a Cantabrian conveyance pathway distance of only 80 km (Fig. 3). Both of these toolstones were identified in their greatest quantities at El Juyo cave, despite the fact that El Mirón and El Rascaño are sites closer to these raw material outcrops. While it is possible that Treviño and Urbasa could have been imported to a single location—El Juyo—and then redistributed locally (following Fig. 3), based on the evidence previously discussed about embedded procurement and toolkit maintenance, the alternate hypothesis that LCM groups gradually shifted their ranges or annual territories and maintained these raw materials in small amounts as they made the ~120 km journey from western Navarra into Cantabria offers a better explanation for the variation exhibited in all of the Cantabrian assemblages examined here. Presumably, these materials would have been reduced through the course of daily activities during this journey, explaining why the toolstones occur in small amounts and, overwhelmingly, in late stage reduction at Cantabrian sites.

Finally, there are four geographically unknown raw materials that were identified at every Cantabrian site sampled: Group F, a material recovered in all reduction stages at every site, and thus probably having a local origin; F1, identified in mid-late stage at Altamira, late stage at El Rascaño, and indeterminate reduction stages at El Juyo and El Mirón; F87, found in all stages at El Rascaño, mid-late stage at El Juyo, late stage at El Mirón, and indeterminate reduction stage at Altamira; and QC1, which signals late stage
Fig. 4. Models of Local Raw Material Conveyance from Four Geographically Unknown Outcrops

Transport pathways for four geographically unknown raw materials: Flints 1 and 87, Group F flints, and Quartz/Calcite 1. Progressive weight decrease, as described in the Fig. 2 caption, determined conveyance order. Dashed circles propose hypothetical catchment zones around sites where each raw material in all stage reduction is in its greatest amount; it is possible that these materials originate near these locations. Lines shown between sites model inter-site connection, but not exact Last Glacial transport routes.

reduction at Altamira and El Rascaño and indeterminate stage reduction at El Juyo and El Mirón (Fig. 4). Each of these raw materials shows a different multi-site conveyance pathway: Group F flints, an ~80 km eastward pathway from El Juyo to Altamira, El Rascaño, and El Mirón; F1, an ~100 km circular trajectory from El Juyo to El Mirón, El Rascaño, and Altamira; F87, an ~127 km crisscross pattern from El Rascaño to El Juyo, El Mirón, and Altamira; and QC1, an ~80 km westward movement from El Rascaño to El Mirón, El Juyo, and Altamira. Apart from Group F flints, LCM groups probably conveyed these materials, identified in overwhelmingly end-stage reduction, into Cantabria from elsewhere. These four materials demonstrate dynamic LCM land use that
included exploiting localized environmental patchworks while balancing east/westward movement through a larger regional territory.

6.6 Local- to Landscape-Level Mobility Models

Four landscape-level models were created to assess the relationships between the local and territorial movements that LCM groups made. Each model has two components: first, landscape-level conveyance pathways (indicated by the green, orange, blue, and purple trajectories presented in Fig. 5) that demonstrate the distance decay of geographically known toolstones in each assemblage; second, local conveyance trajectories that signal transport of the raw material that is the greatest portion of each sites’ assemblage throughout the Cantabrian region (greyscale paths in Fig. 5). These hypothetical scenarios testify to the overall uniformity of the Cantabrian assemblages. Each site has a pathway that either begins in or traverses the region southeast of Cantabria, where the Treviño or Urbasa outcrops are located. Each pattern also testifies to the importance of coastal resources: coastal toolstone outcrops were exploited following an east-west trajectory that corresponds to embedded raw material procurement as groups traversed the Cordillera and arrived into the Cantabrian portion of their territory. The El Juyo raw material assemblage offers perhaps the most compelling case for large-scale LCM group movements because it has small portions of Llaranza and Cabo Mayor— sources local to the site—in its assemblage (see section 6.2 for further explanation regarding Chalosse flint). Based on the model, groups who occupied El Juyo acquired Llaranza and Cabo Mayor flints in Cantabria, traversed the Cordillera to exploit the Urbasa and Treviño outcrops, then journeyed north to the coastal Barrika and Sonabia outcrops before returning to El Juyo and conveying Sonabia flints to El Rascaño,
Fig. 5. Local to Landscape Mobility Models for Lower Cantabrian Magdalenian Sites
This figure combines local- and landscape-level conveyance models for each site sampled. Local conveyance is shown for the raw material that is the greatest portion of each assemblage (Llaranza at Altamira, Barrika and El Mirón, and Sonabia at El Juyo and El Rascaño), and is based on raw material weights and distance decay, as described in the Fig. 2 caption. Landscape-level conveyance is based on the proportion (by weight) of each geographically known raw material in each archaeological assemblage, again assuming distance-decay in outcrop access order, where the toolstones that are the greatest portions of each assemblage were visited most recently. Raw material outcrops are numbered following the description in the Fig. 1 caption. Landscape-level mobility progressions (listed from most to least recently accessed) are as follows for each site: Altamira (shown in green shades) from Llaranza, Sonabia, Barrika, Urbasa, and Treviño; El Juyo (shown in orange shades) from Sonabia, Barrika, Treviño, Urbasa, Llaranza, Cabo Mayor, and Chalosse; El Mirón (shown in blue shades) from Barrika, Llaranza, Sonabia, Treviño, Bidache, and Urbasa; and El Rascaño (shown in purple shades) from Sonabia, Llaranza, Barrika, Urbasa, and Treviño. Lines that connect sites and outcrops model inter-locational relationships, but are not intended to represent exact Last Glacial transport routes.

Altamira, and El Mirón. Together, these four models echo the same maximum territorial extent, demonstrating that LCM groups who occupied Altamira, El Juyo, El Mirón, and El Rascaño not only shared the same diagnostic, artistic “ethnicity” (see González Morales and Straus 2009), but the same landscape-level economic system organized, at least in part, to acquire high-quality flints.

7. Discussion

LCM hunter-gatherer groups formed an economically well-defined regional band that traversed a large territory spanning from Asturias, through a Cantabrian “crossroads”,
into western Navarra. The LCM territorial extension to the Urbasa and Treviño flint outcrops represents a 60% territorial size increase from the ten coastal valleys where LCM palimpsests with engraved scapulae have been identified and excavated. This additional territory may only have been used seasonally—upland valleys would have been accessible routes through the low, eastern (“Basque”) sector of the Cordillera, especially during warmer periods (Clark 1981; Pokines 2001). Seasonal transhumance would have allowed LCM groups to efficiently exploit the resources available in northern Spain while simultaneously expanding their resource base. It is also possible that LCM hunter-gatherers had fluctuating long-term mobility (see Binford 1982, 1983; Kelly 1992) related to annual ranges and resource availability (e.g. rising/falling/shifting faunal populations). Long term mobility strategies would have enabled LCM groups to respond to resource stress through shifting their annual ranges, changing locations and/or sizes, gradually circulating from western Navarra through Cantabria and Asturias in a compounding series that is now compressed in archaeological deposits.

Long-term mobility would have influenced LCM hunter-gatherers’ toolkit organization in several ways. These assemblages indicate that LCM groups maintained (see Bleed 1986) their toolkits through raw material procurement, managing multiple toolstones concurrently: either transporting nuclei among sites as mobile toolkit components or reducing them in situ to supplement the conveyed toolkit. These combined behavioral strategies formed archaeological analytic nodules that testify to all, early, mid, late, and/or indeterminate lithic reduction stages at each LCM cave occupation. Embedding lithic procurement around other tasks and later maintaining these materials within mobile toolkits would have been an advantageous LCM economic
adaptation, both reducing the amount of time that these groups would have spent acquiring toolstones and ensuring that sufficient materials were available to create blanks as necessitated by daily tasks. Additionally, the wealth of raw materials identified in Cantabrian assemblages suggests that these strategies were employed whether LCM groups were transporting raw materials long distances (e.g., Treviño or Urbasa) or short distances (e.g., Barrika or Llaranza), suggesting that embedded procurement and toolkit maintenance were systemic adaptive strategies that probably influenced other aspects of lithic economic behavior (e.g., manufacture, use, and discard) (Andrefsky 1994).

Finally, the lithic raw materials and conveyance patterns identified at the Cantabrian LCM sites suggest that the hunter-gatherers had interlocking scalar economies and may have balanced several distinct mobility systems as they organized their behavior:

- site-catchment zones, where groups procured local raw materials that they reduced in all stages at individual sites;
- sub-regional territories, where groups moved between environmental zones, conveying lithic toolstones among settlement loci;
- long term (seasonal/annual?) ranges, wherein groups gradually shifted east-west or west-east within the maximum territorial extent; and
- inter-territorial networks, evidenced by exotic toolstones like Chalosse and Bidache, which may attest to inter-group material exchanges (in addition to mates, ideas, etc.), presumably at aggregation sites.
The lithic toolstones identified among Cantabrian sites indicate that LCM hunter-gatherers created a complex economic system in which maintenance—of toolstones, toolkits, and territories—was a central characteristic.

**8. Conclusion**

While there are missing elements in the LCM archaeological record (submerged and/or open air sites) and dimensions of mobility that archaeologists cannot account for (i.e., who moved, how often, an occupation’s duration [see Kelly 1992]), this study has shown that LCM hunter-gatherers, who formed a distinctive, Lower Magdalenian regional band (González Morales and Straus 2009), shared an economic system that intensively exploited the Cantabrian environmental patchwork. These groups conveyed lithic raw materials among their settlement loci as part of a scalar economy, maintaining their mobile toolkits as they traversed a large territory. The lithic raw material assemblages from Altamira, El Juyo, El Mirón, and El Rascaño demonstrate that mobility was a defining characteristic of LCM hunter-gatherer lifeways. These groups were tied to the landscape—to lithic outcrops, to fluctuating faunal resources, to shifting territories inhabited by other Lower Magdalenian groups—yet also bonded to their landscape, the caves they occupied and modified, the sites that today define their archaeological culture and distinguish it from the rest of what was, c.16,000 uncal. years ago, a developing Magdalenian world.

**Acknowledgements**

We would like to thank Carmen Cacho for the invitation to participate in this edited issue of *Quaternary International*. Fontes acknowledges the Museo Nacional de Altamira staff, especially Maricer de la Cerca González Enríquez, Carmen de las Heras
Martín, Alfredo Prada Freixedo, and Begonia Blanco Padró, who were extremely helpful during her research stay. The El Mirón collections are curated in the Museo de Prehistoria y Arqueología de Cantabria. Fontes is grateful to the Instituto Internacional de Investigaciones Prehistoricas de Cantabria for providing her laboratory space to analyze the El Mirón collection. A National Science Foundation Doctoral Dissertation Improvement Grant (#1318485), the University of New Mexico Latin American and Iberian Institute Ph.D. fellowship, and an American Association of University Women American Dissertation Fellowship funded Fontes’ research. Excavations of the human burial in El Mirón cave were authorized by the Government of Cantabria and were funded by the Government of Cantabria, the L.S.B. Leakey Foundation and the UNM Fund for Stone Age Research (principal donors: Jean and Ray Auel).
Table 1. Portions of Raw Material Types in Lower Magdalenian Assemblages

Assemblage portions (%) are based on the weight of each raw material (or grouping of raw materials) in grams as a portion of the total weight of each sample assemblage. “Local” materials refer to those toolstones identified at single sites. “Conveyed” materials refer to those stones that were transported between the sites, but whose outcrop locations are unknown. Materials with known geographic outcrops are listed individually. *These raw materials are identified only at these sites; because they are geographically known they are not considered with the “Local” toolstone portion.

<table>
<thead>
<tr>
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<th>El Mirón</th>
<th>El Rascaño</th>
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<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Chalosse Flint</td>
<td>--</td>
<td>&lt;0.01*</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
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<td>--</td>
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### Table 2. Lithic Reduction Stages for Raw Materials Identified at Single Sites

Stage attributions are as follows: A=All Stages; E=Early Stage; M=Mid Stage; L=Late Stage; I=Indeterminable Stage. Stones with more than one stage determination (but not all stages) are listed together, as in “ML” to signify “Mid and Late Stages”. Raw material types are abbreviated based on their numbers in the Cantabrian Raw Materials Database created by Fontes; more information are available upon request. Raw material type abbreviations are as follows: F=Flint (as in “F36” is “Flint 36”); QZ=Quartzite; QC=Quartz and/or Calcite; L=Limestone; M=Mudstone or Lutite; O=Other Materials; and U=Unknown Stone.

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</tr>
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<td></td>
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Table 3. Approximate Linear Distances Between Lower Cantabrian Magdalenian Sites and Flint Outcrops

_Distances are in kilometers._

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<th>El Rascaño</th>
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Table 4. Lithic Reduction Stages for Raw Materials Conveyed Between Sites

Table is divided into three sections: (a) raw materials conveyed between two sites; (b) raw materials conveyed among three sites; and (c) raw materials conveyed among all four sites. Stage attributions are as follows: A=All Stages; E=Early Stages; M=Mid Stage; L=Late Stage; I=Indeterminable Stage. Stones with more than one stage determination (but not all stages) are listed together, as in “ML” to signify “Mid and Late Stages”. Weights are listed in grams. Raw material types are abbreviated based on their numbers in the Cantabrian Raw Materials Database created by Fontes; more information are available upon request. Raw material type abbreviations are as follows: F=Flint (as in “F36” is “Flint 36”); QZ=Quartzite; QC=Quartz and/or Calcite; L=Limestone; M=Muds tone or Lutite; O=Other Materials; and U=Unknown Stone. Group F flints are five visually distinct materials often found together on single artifacts; they likely originate from a highly variable outcrop.

### (a) Two Sites

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### (b) Three Sites

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Table 4 (con’t).

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<td>A 517</td>
<td>M 0.6</td>
<td>ML 232</td>
</tr>
<tr>
<td>Group F Flints</td>
<td>A 1250.1</td>
<td>A 1605</td>
<td>A 125.3</td>
<td>A 757.2</td>
</tr>
<tr>
<td>F1</td>
<td>ML 221</td>
<td>I 10.2</td>
<td>I 17.4</td>
<td>L 127.1</td>
</tr>
<tr>
<td>F87</td>
<td>I 2.2</td>
<td>ML 17.1</td>
<td>L 8.7</td>
<td>A 40.8</td>
</tr>
<tr>
<td>QC1</td>
<td>L 7.2</td>
<td>I 15.3</td>
<td>I 18.4</td>
<td>L 34.6</td>
</tr>
</tbody>
</table>
Table 5. Distance Decay and Inter-site Conveyance Pathways

Single and multiple conveyance pathways are based on distance decay, which assumes that toolstones were depleted as groups moved from sites further from source outcrops. In each conveyance pathway, the site listed first has the greatest quantity (by weight) of the raw material(s) conveyed on that pathway; the last site listed has the least quantity. Single conveyance pathways summarize both raw materials conveyed between two sites and each conveyance stage for those toolstones transported among three and four sites. Multiple conveyance pathways summarize both raw materials conveyed among three sites or among four sites with these conveyance stage patterns.

<table>
<thead>
<tr>
<th>Single Conveyance Pathway</th>
<th>Conveyed Materials (#)</th>
<th>Raw Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altamira to El Juyo</td>
<td>6</td>
<td>F65, F81, QZ9, QZ22, QZ23, U6</td>
</tr>
<tr>
<td>Altamira to El Mirón</td>
<td>3</td>
<td>Llaranza, Sonabia, L1</td>
</tr>
<tr>
<td>Altamira to El Rascaño</td>
<td>7</td>
<td>Urbasa, Group F, F1, F20, F32, F66, QZ7</td>
</tr>
<tr>
<td>El Juyo to Altamira</td>
<td>4</td>
<td>Urbasa, Group F, F66, QC1</td>
</tr>
<tr>
<td>El Juyo to El Mirón</td>
<td>3</td>
<td>F65, F87, M3</td>
</tr>
<tr>
<td>El Juyo to El Rascaño</td>
<td>5</td>
<td>Barrika, Sonabia, Treviño, F29, F37</td>
</tr>
<tr>
<td>El Mirón to Altamira</td>
<td>3</td>
<td>Treviño, F87, QC2</td>
</tr>
<tr>
<td>El Mirón to El Juyo</td>
<td>5</td>
<td>Barrika, F1, QC1, QC4, QZ5</td>
</tr>
<tr>
<td>El Mirón to El Rascaño</td>
<td>4</td>
<td>Llaranza, O4, QZ1, QZ6</td>
</tr>
<tr>
<td>El Rascaño to Altamira</td>
<td>5</td>
<td>Barrika, Sonabia, F29, O4, QZ6</td>
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<tr>
<td>El Rascaño to El Juyo</td>
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<td>Llaranza, F50, F87</td>
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<tr>
<td>El Rascaño to El Mirón</td>
<td>6</td>
<td>Treviño, Urbasa, Group F, F1, L2, QC1</td>
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Table 5 (con’t)

<table>
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<th>Multiple Conveyance Pathway</th>
<th>Conveyed Materials (#)</th>
<th>Raw Materials</th>
</tr>
</thead>
<tbody>
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<td>F65</td>
</tr>
<tr>
<td>Altamira, El Mirón, El Rascaño</td>
<td>1</td>
<td>Llaranza</td>
</tr>
<tr>
<td>Altamira, El Rascaño, El Mirón</td>
<td>3</td>
<td>Urbasa, Group F, F1</td>
</tr>
<tr>
<td>El Juyo, Altamira, El Rascaño</td>
<td>3</td>
<td>Urbasa, Group F, F66</td>
</tr>
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<td>El Juyo, El Mirón, Altamira</td>
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<td>F87</td>
</tr>
<tr>
<td>El Juyo, El Rascaño, Altamira</td>
<td>3</td>
<td>Barrika, Sonabia, F29</td>
</tr>
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<td>El Juyo, El Rascaño, El Mirón</td>
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<td>Treviño</td>
</tr>
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<td>El Mirón, El Juyo, Altamira</td>
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<td>QC1</td>
</tr>
<tr>
<td>El Mirón, El Juyo, El Rascaño</td>
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<td>Barrika</td>
</tr>
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<td>El Mirón, El Rascaño, Altamira</td>
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<td>O4, QZ6</td>
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<td>Llaranza</td>
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<td>Sonabia</td>
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</tr>
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<td>Treviño</td>
</tr>
<tr>
<td>El Rascaño, El Mirón, El Juyo</td>
<td>2</td>
<td>F1, QC1</td>
</tr>
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Chapter 5: Lithic Toolstone Production Efficiency and Lower Magdalenian Adaptive Strategies in Cantabria, Spain

The manuscript presented in this chapter was authored by Lisa M. Fontes, Lawrence Guy Straus, and Manuel R. González Morales and is under review by the Journal of Archaeological Method and Theory. Fontes wrote the article and has included Straus and González Morales as co-authors because she used data from El Mirón Level 504 in the analysis.

1. Introduction

Anthropologists and archaeologists have a longstanding interest in hunter-gatherers (e.g., Bettinger 1980; Bicchieri 1972; Binford 1978; Cox 1973; Hayden 1981; Kelly 1932; Lee and DeVore 1968; Lothrop 1928; Murdock 1967; Netting 1977; Williams and Hunn 1981). Movement is a central aspect of forager lifeways; moreover, how groups moved reflects their adaptations to the environments they lived in—their responses to local conditions (Kelly 2007). Archaeologists who study mobility have often focused on how groups procured resources (i.e., toolstones, comestibles, etc.) and their subsequent distribution throughout the landscape as major factors that influenced hunter-gatherer movement (see Beck et al. 2002; Bettinger and Baumhoff 1982; Binford 1980; Kelly 1988; Kelly and Todd 1988; Kuhn 1991, 1994; Shott 1986, 1989; Jones et al. 2003, 2012; among others). These kinds of archaeological studies, along with ethnoarchaeological and ethnographic research, have helped anthropologists document the significant diversity in hunter-gatherer lifeways and understand how flexibly humans can adapt to environmental variation (Binford 1978; Gould 1980; Kelly 2007). This paper approaches hunter-gatherer adaptations, particularly lithic procurement, toolkit structure,
and mobility, through the lens of lithic technology. Lithic artifacts are particularly well suited to landscape-level mobility studies because they were made using reductive techniques. Archaeologists can trace lithic artifacts to particular moments in reduction sequences and make regional comparisons based on the distance-decay principle (i.e. the fact that lesser quantities of a material will be present the further one is from that material outcrop) to reconstruct how far groups may have moved (Binford 1977, 1978, 1979, 1980; Carr 1994b; Fontes et al. in press; Kelly 1988; Kuhn 1991; Odell 1996; Torrence 1989). This paper uses a mathematical model to explore one factor that may have influenced hunter-gatherer group movement: the production efficiency of lithic raw materials. This model is applied to a case study of four sites in Cantabrian (Atlantic coastal) Spain that were occupied during the Lower Magdalenian period (c. 16-14,000 uncal. BP). Results indicate that lithic raw materials that were used for bladelet production were the most productive, consequently influencing hunter-gatherer mobile toolkit management (i.e., toolstone conveyance and mobility) and lithic procurement strategies.

2. Hunter-Gatherer Mobility

described as residential or logistical, a characterization of how often people move and the nature of the movement. These groups also can be characterized as foragers or collectors, a description of whether people subsist by moving themselves to resources or moving resources to themselves (Bettinger 1987; Binford 1976, 1980; Bousman 1993; Kelly 1983). Each continuum is not meant to be dichotomous, but a spectrum that hunter-gatherer organizational systems will fall on. Hunter-gatherer mobility strategies will include various elements of these continua based on local circumstances (Binford 1980). Additionally, hunter-gatherer mobility will also likely reflect how groups managed long- and short-term foraging goals (Bousman 1993). Hunter-gatherer mobility strategies would have also been adapted to local resource stress, which could include substantial seasonal variation (Kelly 1996; Speth and Spielman 1983). Foraging groups could adapt to environmental variation by managing their territory size, expanding and/or contracting their habitual ranges to broaden, attenuate, or shift their resource base (Binford 1982, 1983; Fontes et al. in press; Jones et al. 2003, 2012; Kelly 1992). Another way that hunter-gatherers could prevent resource shortfalls is through connections with other regional groups; these are important contacts to consider when structuring a settlement system (Binford 1991; Riolo et al. 2001; Smith and Wishnie 2000; Speth 1990). However, social contacts, including the frequency of group moves and who actually moves (i.e., individuals or entire groups), are often difficult to discern archaeologically, and while acknowledged as important factors in prehistoric lifeways, are generally not the subject of archaeological mobility studies (Kelly 1992, 2007).
3. Anthropological Approaches to Mobility

Archaeologists generally agree that regional lithology, i.e., the availability of particular lithic toolstones on a landscape, will influence how hunter-gatherers structured their settlement systems (Andrefsky 1994; Bamforth 1986, 1991; Kuhn 1991). Archaeologists who study mobility and lithic technology generally distinguish two approaches: first, characterizing the lithic raw materials that prehistoric groups exploited via source provenance analysis (see examples in Anderson and Hanson 1988; Beck and Jones 1990; Boldarian 1991; Buck et al. 1996; Chalard et al. 2010; Hofman 1992; Jones et al. 2003, 2012; MacDonald 1968; Reher and Frison 1980; Seeman 1994; Tankersly 1990; Tarriño et al. 2014); and second, focusing on lithic technological organization patterns (see Binford 1977, 1978, 1979, 1980; Carr 1994b; Fontes et al. in press; Kelly 1988; Kuhn 1991; Odell 1996; Torrence 1989). The first approach is largely used to determine the extent of hunter-gatherer territories, since it cannot account for how groups acquired the raw materials (i.e., directly or through trade) (Kelly 2007). The second approach, lithic technological organization, is a framework that summarizes the strategies prehistoric groups followed to select, make, use, and transport stone materials (Nelson 1991:57). Lithic raw material procurement is a major aspect of technological organization that would have influenced technological decisions, including manufacturing methods and tool-use intensity (Andrefsky 1994; Bamforth 1991; Ericson 1984). Lithic raw material selection would have been influenced by raw material abundance and quality, as well as by a site’s occupational intensity (Andrefsky 1994; Bamforth 1990; Carr 1994a, 1994b; Dibble 1991; Surovell 2009), in turn impacting settlement decisions. It is also possible that hunter-gatherers differentiated their use of lithic tool stones and mobility
patterns based on cultural territories (Binford and O’Connell 1984; Brantingham 2006; Ingbar 1992; Rosenberg 1998). Since raw material procurement would have involved both cultural and environmental factors, archaeologists can assess it in terms of what Nelson (1991:58) terms strategy, the processes, such as mobility, that prehistoric groups followed to respond to the conditions created by human-environmental interactions. Archaeologists have often focused on landscape-level data to understand past human behavior in these broad terms, approximating the scale at which prehistoric groups interacted with their environments (see Binford 1976, 1978, 1979, 1980, 1991; Ericson 1984; Gould 1980; Kuhn 1989; Thacker 2000; Rensink 1995, 2000; among others). Technological strategies are therefore constrained by regional lithology and what were culturally considered optimal solutions (movement, tool curation, etc.) (Andrefsky 1994; Bamforth 1986, 1991; Kuhn 1991; Nelson 1991). Archaeologically, these strategies will both spatiotemporally vary and be influenced by site formation processes (Binford 1980; Nelson 1991).

3.1 Human Behavioral Ecology

HBE is a general theory in anthropology derived from Evolutionary Ecology and focused on the evolution of adaptive behavior (Foley 1985; MacArthur and Pianka 1966; Winterhalder and Smith 2000). Archaeology’s HBE researchers often frame human decisions based on optimal foraging theory (OFT), asserting that humans will strive to be optimal, and that the more optimal they are the better their reproductive fitness will be (Foley 1985; Smith 1983; Winterhalder and Smith 2000). Optimality is often used as the main tenet in models related to food choices, including the diet breadth model, marginal value theorem, patch choice model, central place model, and group size model, among
others (see for examples Bettinger et al. 1997; Bird and Bliege Bird 1997; Boone 2002; Foley 1985; Hames 1989, 1992; Hames and Vickers 1982; Hawkes et al. 1982; Kelly 2007; Metcalfe and Barlow 1992; Schoener 1971; Smith 1979, 1983, 1987; Smith and Winterhalder 1992; Vayda and McCay 1975; Winterhalder 1983; Winterhalder and Smith 2000). In these kinds of models, foragers avoid failure by having the most efficient feeding behavior; differences in feeding behavior will affect reproductive success (Foley 1985; Hames and Vickers 1982; Kelly 2007; Schoener 1971; Winterhalder and Smith 2000). Optimality models may account for differences in human behavior by defining foraging goals, currencies, a phenotypic set (range of available behaviors), time frames, and competition (for resource access) as potential model components, though even with all of these variables, models are approximations far simpler than behavioral reality (Foley 1985; Smith 1983; Winterhalder and Smith 2000). While optimality models predict that organisms will trend toward optimization, the expectation is that they will never actually be optimal because there is a lag time between environmental change and adaptation (Foley 1985; Hames and Vickers 1982). Additionally, optimal behavior is not a static response to environmental conditions: it will covary with environmental variance (Hames and Vickers 1982). Overall, OFT provides a method to study environmental parameters that constrain foragers and make predictions about forager response to conditions; through this OFT can help archaeologists explain adaptive processes (Hames and Vickers 1982).

When operationalized, OFT is often framed economically, wherein decisions are made based on potential costs and benefits (Foley 1985; Smith 1983; Winterhalder and Smith 2000). Technological decisions are a common subject of HBE modeling because
technology incurs costs (in design, procurement, manufacture, etc.) and later reaps benefits in subsistence systems (Bousman 2005; Myers 1989). In mathematical HBE models, technological efficiency is often measured using currencies like production time, tool use life, and volume (Bousman 1993). Using HBE models, archaeologists have focused on optimal tool manufacture (i.e., issues of design advantages) (Bleed 1986; Eerkens 1998), or on lithic technological systems (Myers 1989; Torrence 1989).

Fundamentally, lithic technologies must solve problems of procurement, production, and accomplishing tasks. Successful (optimal) technological adaptations will take advantage of opportunities and cope with constraints to achieve the highest possible return rates for foragers (Bamforth and Bleed 1997; Fitzhigh 2001). The lithic technological organization framework emphasizes how decisions that hunter-gatherers make at one point in a technological system will strongly influence what happens at a later moment in the system because lithic technology is reductive (Bamforth and Bleed 1997). Thus, lithic technologies are determined within the context of a whole adaptive system and will vary regionally in response to particular circumstances (Bousman 1993). Consequently, archaeologists are often concerned with lithic technology’s role in prehistoric mobility, the context in which tool stones are acquired and later used in manufacturing, maintenance, use, and discard (Andrefsky 1994; Ericson 1984; Nelson 1991; Torrence 1989). By modeling optimal raw material acquisition, archaeologists can better understand how foragers managed environmental variation and created stable technological systems. Recently, two HBE models of raw material procurement have been proposed. The first, Brantingham (2006), is concerned with raw material transport distance and planning depth. Brantingham (2006) asserts that these factors are a function
of risk sensitivity (in planning) and optimization (of mobility). The second, Surovell (2009), proposes a “rainy day” model contrasting how much toolstone people procured with how much they used and relating it to site occupation span. Both of these models provide greater understanding for how people procure resources, transport them, and stockpile them. This paper proposes a slightly different approach: modeling toolstone production efficiency, which in turn can help archaeologists understand why hunter-gatherers accessed and utilized particular lithic raw materials and how they scheduled these activities within their landscape-level adaptive strategies.

4. The Lower Magdalenian in Cantabria, Spain

The Lower Cantabrian Magdalenian period (LCM; c. 16-14,000 uncal. years BP), took place during the latter part of Oldest Dryas, a climatic phase after the Last Glacial Maximum, which was characterized by a relatively dry, cold climate (Hoyos 1995). The landscape had a combination of heath steppe, herbaceous, and tundra vegetation, but it was mostly treeless, with only scattered pines, birches, and junipers (Hoyos 1995; Iriarte et al. 2015; Pokines 2000). The LCM is a unique regional Magdalenian archaeological culture that was probably created by several interacting bands localized within some 10-12 river valleys in modern Cantabria and eastern Asturias provinces along the northern Spanish coast (Conkey 1980; González Morales and Straus 2009; Straus 1992, 2013; Utrilla 1981, 1996, 2004; Fig. 1). It can be distinguished from other regional Magdalenian cultures (e.g. in southwest France, the upper Ebro River Basin, the Pyrenees) based on unique elements of its material culture, which include quadrangular-section antler sagai̇es with “tectiform” engravings, engraved red deer scapulae with striated depictions of red deer hinds and other ungulates, and large quantities of so-called
nucleiform endscrapers and/or backed bladelets in lithic assemblages (González Echegaray 1960; González Morales and Straus 2009; González Morales et al. 2007; González Sainz 2005; Straus 1992, 2005, 2013; Utrilla 1981, 1996, 2004). These items are recovered from extraordinarily rich palimpsest deposits that often attest to functional complexity, with hearth features, abundant fire-cracked rocks and faunal remains (ibex in montane zones and [shell]fish and red deer in coastal ones), spatially delimited activity areas, and complex structures (Barandiarán et al. 1985; Marín Arroyo 2009; Nakazawa et al. 2009; Straus 1992, 2005, 2013; Utrilla 1981). LCM hunter-gatherers may have moved principally among coastal residential sites (e.g. Altamira, El Juyo), using smaller caves as special purpose satellite camps where they could pursue game not available in the coastal zone (e.g. El Rascaño, a montane site that was an ibex hunting location) (Altuna 1972; Straus 1986, 1987, 1992, 2013; Straus and Clark 1986; Straus and González Morales...
2012b; Utrilla 1981). The LCM is an ideal case study to explore the relationship between mobility and lithic technological organization because the culture is archaeologically, environmentally, geographically, and temporally well defined (González Echegaray 1960; González Morales and Straus 2009; Straus 2013).

4.1 Altamira Cave

M. Sanz de Sautuola (1880) first discovered parietal art and human occupations in Altamira cave (Santillana del Mar), which is located 65 meters a.s.l., near the Río Saja, in an open, rolling landscape in the Cantabrian coastal plain approximately 10 km from the Oldest Dryas shoreline (Freeman and González Echegaray 2001). The site was excavated several times, first by Sautuola (1880), then H. Alcalde del Río (1906), H. Obermaier (Breuil and Obermaier 1912, 1913, 1935), and more recently by L. Freeman and J. González Echegaray (2001) in 1980-1981 and J.A Lasheras and C. de las Heras in 2004 and 2006 (Lasheras et al. 2007). This analysis focuses on those materials recovered during Freeman and González Echegaray’s excavation of Level 2. Freeman and González Echegaray recovered archaeological remains from a small, ~4 m² area of Altamira’s vestibule, which they dated to 15,910±230 uncal. BP (I-12012) (González Echegaray 1988). Their analyses indicate that the site was occupied during the fall through spring, and that the site’s inhabitants exploited red deer (*Cervus elaphus*), fish, and shellfish (*Patella* and *Littorina*) (Freeman 1988; Freeman and González Echegaray 2001). Due to its abundant parietal and portable art and rich archaeological remains, archaeologists have hypothesized that Altamira was a location for seasonal aggregations wherein groups collectively pursued local resources—“wild harvesting” red deer herds, for example (see Freeman 1973)—and later dispersed, profiting from both the comestible surplus attained
in the large group and the inter-band connections they maintained (Conkey 1980; Pokines 2001; Straus 1975-1976, 2013).

4.2 El Juyo Cave

El Juyo (Igollo) is a large cave also located in coastal Cantabria, approximately 12 km from the Oldest Dryas shore (Barandiarán et al. 1985). The site is 60 m a.s.l., with slightly higher, 100 m a.s.l. hills nearby that provide views of the local terrain (Barandiarán et al. 1985; Pokines 2001). El Juyo contains a major LCM palimpsest deposit with several occupation levels; three of these have been radiocarbon dated: Level 7 to 14,440±180 uncal. BP (I-10738); Level 6 (in error) to 11,400±300 uncal. BP (I-10737); and Level 4 to 13,920±240 uncal. BP (I-10736) (Barandiarán et al. 1985). Faunal remains from El Juyo indicate that salmon and red deer were key food species for the site’s occupants; both were heavily exploited using “wild harvesting” techniques (Barandiarán et al. 1985; Freeman 1973; Klein et al. 1981, 1983; Pokines 2001). The site was occupied from late fall through the late spring (Pokines 2001). El Juyo is also known for its bladelet technology. These “Juyo” bladelets (microblades) are exceptionally small and lightly retouched, and were likely used in LCM composite weapons systems (Barandiarán et al. 1985; González Echegaray and Freeman 2007). Level 6 is the subject of this analysis.

4.3 El Mirón Cave

El Mirón (Ramales de la Victoria), is located in montane interior Cantabria, surrounded by ≥1000 m peaks, approximately 25-30 km from the Last Glacial coast (González Morales and Straus 2005; Straus and González Morales 2003; Straus et al. 2008). The cave has a large, west-facing vestibule that overlooks the Asón river valley
(Straus et al. 2015). The site has been under continuous investigation led by L.G. Straus and M.R. González Morales since 1996; their work has resulted in one of the best-dated Upper Paleolithic sequences in Cantabria (González Morales and Straus 2009; Straus and González Morales 2003, 2007, 2010, 2012a; Straus et al. 2008; Straus et al. 2015). Their team has recovered archaeological remains from outer, middle, and rear vestibule areas, including the human burial in its rear southeast corner (Straus et al. 2015). This analysis focuses on the lithic artifacts recovered from the burial area Level 504 (Fontes et al. 2015). This context was dated to the Lower Magdalenian by two assays yielding dates of 15,460±40 (MAMS-14585) and 15,740±40 (UGAMS-7217) (Straus et al. 2015). Faunal analyses by Marín Arroyo and Geiling (2015) indicate that the hunter-gatherers who lived here exploited ibex and red deer during the winter and spring. The site has also yielded extraordinary amounts of lithic debitage, especially bladelets and bladelet cores, indicating that microlith production was a major activity occurring at El Mirón (Fontes et al. 2015; Straus et al. 2008).

4.4 El Rascaño Cave

El Rascaño (Mirones), is situated 275 meters above sea level, in an abrupt, montane landscape approximately 32 km from the Oldest Dryas coastline (González Echegaray and Barandiarán 1981). The LCM occupation in the cave, dated to 15,988±193 uncal. BP (B.M. 1453), was recovered from a small sector in the rear of the cave (González Echegaray and Barandiarán 1981). The deposits included many diagnostic LCM artifacts, including nucleiform endscrapers, antler sagaiés, and a striation-engraved red deer scapula (Straus 1992). The site is thought to have been a specialized ibex hunting stand based on its faunal assemblage, however, all stages of
osseous industry manufacture have been identified at the site, indicating that diverse activities were carried out at the location (González Echegaray and Barandiarán 1981; González Morales and Straus 2009; Utrilla 1981).

4.5 Vasco-Cantabrian Archaeopetrography

Archaeopetrography is a growing research field in the Vasco-Cantabrian region of north coastal Spain. Lithology varies throughout the region, with the highest quality flints located in Guipúzcoa and Vizcaya in Cretaceous formations; these flints decrease westwardly toward Asturias, where assemblages include large amounts of other materials, such as quartzite and ophite (Rissetto 2004, 2009; Sarabia 1999, 2002; Straus 1996; Tarriño 2000). A few studies have discussed the lithic raw materials available in the area (see Bernaldo de Quirós and Cabrera 1996; González Sainz 1992; Rissetto 2009; Sarabia 1990a, 1990b, Straus et al. 1986, and Tarriño et al. 2014). While some toolstones have been characterized in archaeopetrological collections (see Rissetto 2009; Tarriño et al. 2014), sources for most of the raw materials in Vasco-Cantabrian lithic assemblages remain geographically unknown. However, Fontes et al. (in press) have made exhaustive comparisons of visually distinct lithic raw materials that have helped model hunter-gatherer raw material conveyance throughout Cantabria. The summary presented here focuses on geographically known outcrops, which can be divided into three major groups relative to their proximity to the central Cantabrian region.

4.5.1. Regional Flints

Barrika/Kurtzia/Soplana flysch (Cenomanian-Santonian, Upper Cretaceous) outcrops in a megabreccia formation along the Vizcaya coastline between Bilbao and Plentzia, Spain. The flint is visually distinct, fine grained, and grey (Tarriño et al. 2014).
Llaranza flint (Cenomanian-Santonian, Upper Cretaceous), a very translucent stone that is variable in color, yet typically ranging from yellow-orange to clear-white, occurs along the Cantabrian coast to the east of Santander, Spain (Rissetto 2012). Finally, Sonabia flysch (Albian, Lower Cretaceous), a dark, blue-grey to whitish grey and fine-grained toolstone, outcrops in eastern Cantabria near the modern coastal town of Oriñon, between Laredo and Castro Urdiales. These three raw materials have been identified in archaeological sites throughout north coastal Spain (Corchón et al. 2007; Fontes et al. in press; Rissetto 2012; Tarriño 2006, 2012; Tarriño et al. 2013, 2014).

4.5.2. Extra-Regional Flints

Two extra-regional trans-cordilleran flints are also included in this paper: Treviño and Urbasa. Treviño flint (Miocene), a toolstone that is brown and extremely fine-grained, outcrops in the Miranda-Treviño Depression (Álava, Spain), and has been recovered in nearly all of the archaeological sites in the Cantabrian region where archaeopetrographic studies have been made (see: Corchón et al. 2007; Fontes et al. in press; Tarriño 2000, 2012; Tarriño and Aguirre 1997; Tarriño et al. 2014). Urbasa flint (Paleocene, outcropping in Sierra de Urbasa, NW Navarra, Spain) is distinguished by its unique echinoderms, macroforaminifera, and microdolomitization that have made it identifiable in collections from archaeological sites over 300 km from its outcrop location in several Upper Paleolithic settlement areas: Cantabria, the western Pyrenees, and the Aquitane (Corchón et al. 2007; Fontes et al. in press; Tarriño 2006; Tarriño and Normand 2002; Tarriño et al. 2013, 2014). Due to their ubiquity in Upper Paleolithic lithic assemblages, Treviño and Urbasa flints are both considered tracer stones that can provide information about prehistoric territory sizes and mobility (Tarriño et al. 2014). Additionally, while the
Treviño and Urbasa outcrops are located to the south of the Cantabrian Cordillera, there were low unglaciated passes in the Basque Country that prehistoric groups could have traversed with relative ease to arrive at these sources.

4.5.3. “Exotic” Flints

Two “exotic” toolstone types that outcrop in southwest France have been identified in the Cantabrian archaeological assemblages discussed in this paper: Bidache flysch and Chalosse flint. Bidache (Campanian, Upper Cretaceous), outcrops in the Pyrénées-Atlantiques region between Biarritz and Bidache along the Gaves Réunis river (Normand 2002). This flint is recognizable by parallel turbidic laminations that are quite striking when the material patinates, which has led to its identification in archaeological collections throughout the Cantabrian region (Corchón et al. 2007; Fontes et al. in press; Tarriño 2012; Tarriño et al. 2013, 2014). Chalosse flint has also been identified in archaeological sites throughout the Cantabrian region, far from its outcrop in an Upper Cretaceous marine carbonate platform in southern Les Landes, France (Corchón et al. 2007; Fontes et al. in press; Tarriño 2012; Tarriño et al. 2013, 2014). This toolstone (like Bidache, Treviño, and Urbasa) is considered a tracer flint due to its unique visual characteristics: typically translucent, greyish to blackish in color (but when patinated having distinct yellow-whitish patches), and abundant bioclastic inclusions, especially the macro-foraminifer species *Lepidorbitoides* (Chalard et al. 2010; Tarriño et al. 2014).

Archaeologists have used these two raw materials, and other tracer flints, to reconstruct prehistoric territories and networks (Chalard et al. 2010; Fontes et al. in press).
5. Methodology

5.1 The Production Efficiency Model

Foragers will procure a quantity of lithic raw material \( m \) and will use it to produce a variety of stone products. Flintknappers’ primary concern would have been producing blanks suitable for tools (Andrefsky 1994; Cotterell and Kamminga 1987; Gould 1980). In LCM assemblages (as with many Upper Paleolithic industries), flakes, blades, and bladelets were the primary debitage products (Clark and Straus 1983; Fontes et al. 2015; Straus 1992, 2002; Straus et al. 2008; Utrilla 1981). However, flintknappers will always produce secondary debitage in lithic reduction—angular chunks and shatter in manufacture, trimming flakes through retouch/re-sharpening, burin spall, core slugs, etc. These secondary debitage items reflect how raw materials were used and maintained: they are waste. While flintknappers would have been cognizant that waste would be produced as they created blanks and tools, they would have sought to minimize it (Bamforth and Bleed 1997; Bousman 1993, 2005; Torrence 1989). Modeling production waste would be extraordinarily difficult because these products’ volumes would often depend on factors such as flintknapping skill or internal facture planes in raw materials, which are difficult to predict because they would vary from person to person or core to core. Thus, this model uses a 15% waste rate to account for secondary debitage products and to model the raw material available \( m_a \) for lithic production of primary debitage products:

\[
m * 0.85 = m_a
\]
Manufacturing efficiency will differ depending on the kind of primary debitage produced. Blade and bladelet products make more efficient use of lithic raw materials than flakes, which are less standardized (see Conard 1990; Elston and Kuhn [eds.] 2002; Fisher 2006). Thus, to effectively model a raw material’s production efficiency it is important to understand the rates at which flakes \( r_f \), blades \( r_b \), and bladelets \( r_l \) were produced using that stone. Each of these rates can be calculated by dividing the number of flake, blade, or bladelet products by the total amount of primary debitage. These rates are then used to calculate the proportions of available material \( m_a \) devoted to flake \( f_p \), blade \( b_p \), and bladelet \( l_p \) production, expressed as follows for flakes:

\[
(5.1.2) \quad f_p = r_f \times m_a
\]

This equation can be repeated as necessary to determine the proportion of blades \( b_p \) and bladelets \( l_p \) (the equations that follow will also be explained using the flake example variables, but would be repeated if blades and bladelets were manufactured to determine their contribution to the overall production efficiency of the stone). After determining the proportion of available raw material \( m_a \) that will be used for flake production \( f_p \), the next step is to model how many flakes could be produced from this volume, as follows:

\[
(5.1.3) \quad \frac{f_p}{f_v} = n_f
\]

where the material available for flake production \( f_p \) is divided by average flake volume \( f_v \) to predict the number of flakes \( n_f \) that can be manufactured from it. Flake volume \( f_v \) is based on length, width, and thickness measurements of whole debitage. After modeling the number of flakes \( n_f \) that could be produced, it is possible to determine the amount of cutting edge \( e_f \) that would be produced in lithic reduction, as follows:
\(5.1.4\)

\[ n_f \times f_f = e_f \]

where \(f_f\) is the average length of flakes produced. After determining flake \(e_f\), blade \(e_b\), and bladelet \(e_l\) cutting edges, the production efficiency \(P\) of the available raw material \(m_a\) can be modeled as the total length in millimeters of available cutting edge:

\(5.1.5\)

\[ e_f + e_b + e_l = P \]

\(P\) is a measure of production efficiency for analytic nodules in an assemblage; it will be strongly correlated to the kinds of products flintknappers made from a raw material. Thus, \(P\) is also a proxy for raw material quality—how effectively flintknappers could reduce a standard volume of stone (modeled in this case study as a 150mm\(^3\) [an approximately 6 inch cube]) into a variety of products. Assuming that there is a minimum amount of cutting edge that hunter-gatherers would need in their mobile toolkits in order to complete daily tasks, electing those stones with the greatest potential production efficiency \(P\) would provide groups with the greatest return rate in cutting edge for the least procurement effort—these stones would offer groups the greatest potential for lithic reduction (Bamforth and Bleed 1997; Fitzhugh 2001). Optimal groups will elect the most productive toolstone within a resource patch (MacArthur and Pianka 1966).

5.2 Lithic Analysis

Lithic debitage samples were taken from Altamira Level 2 (n=2346), El Juyo Level 6 (n=1846), El Mirón Level 504 (n=4973) and El Rascaño Level 4/4B (n=1722) (Barandiarán et al. 1985; Fontes et al. 2015; Freeman and González Echegaray 2001; González Echegaray and Barandiarán 1981; Straus et al. 2015). These samples represent all lithic debitage (flakes, blades, and bladelets) from each of these archaeological contexts that are greater than one linear centimeter in size. All lithic artifacts were
analyzed individually, classified using a debris typology that distinguished: whole/fragmentary non-cortical and cortical flakes, blades (>2cm and parallel sided), and bladelets (following Fontes et al. in press). Qualitative and quantitative attributes were recorded for each artifact. Those attributes relevant to this analysis include:

(1) artifact length, width, and thickness to the nearest millimeter for whole debitage (relative to the axis of the piece);

(2) debitage portion, including whole, proximal, mesial, distal, longitudinal, or indeterminable; and

(3) raw material type, which was determined using ad hoc toolstone reference collections that were created for each site and later directly compared to each other. Each reference set separated raw materials based on their: color (including any variations); grain size; texture; homogeneity/inclusions; opacity/translucence; matte/sheen; patina; fracture mechanics; and cortex color/texture (following Fontes et al. in press). All reference materials were compared with two archaeopetrological collections, the first created by A. Tarriño (2012) for Aitzbitarte IV (Guipúzcoa), curated at the Centro de Custodia in San Sebastián, which included samples from Barrkia/Kurtzia, Bidache, Chalosse, Treviño, and Urbasa flint outcrops. The second was made by J. Rissetto (2009), and included samples of Barrika/Kurtzia, Llaranza, and Sonabia flints; this collection is curated at the Instituto Internacional de Investigaciones Prehistóricas de Cantabria at the Universidad de Cantabria.

These attributes provide data about lithic organizational behaviors at Altamira, El Juyo, El Mirón, and El Rascaño caves and their relation to toolstone resource use in the greater Vasco-Cantabrian region.
6. Interpretive Assumptions

At the outset, it is important to note that any mathematical model of human behavior simplifies archaeological and prehistoric reality (Bettinger 2009; Binford 1978, 1979, 1980; Foley 1985; Fontes et al. in press; Gould 1980; Kelly 1992, 2007; Schiffer 1972; Shott 1986; Smith 1983). Several assumptions have been made to operationalize the production efficiency model and to interpret the results in this case study (following Fontes et al. in press):

(1) The first issue that all archaeologists must grapple with is time (Bailey 1983, 2007). Each lithic raw material identified at an LCM site has been summarized as an analytic nodule (see Fontes et al. in press). These units enable detailed inter-site comparisons of toolstone production efficiency while also simplifying variations in how raw materials may have been reduced at each site. It is possible that analytic nodules represent the work of one or many knappers during single or multiple occupations over time at each site considered in the LCM case study. Analytic nodules do not recognize this variation, but instead merge plausible behaviors into a single sequence. “Time averaging” in this manner is a common facet of Paleolithic archaeology (Bailey 1983, 2007). Thus, each analytic nodule summarizes lithic technological behavioral patterns at a particular location, which in turn correspond to patterned landscape use, enabling archaeologists to reconstruct a site’s role within a landscape-level settlement system (Binford 1980; Fontes et al. in press; Straus 1979, 1990, 1997, 2013; Straus and Clark 1986).

(2) Another issue that Paleolithic archaeologists must confront is which areas were sampled during excavations: the sizes and locations of excavated areas could have
influenced the proportions of each analytic nodule in each assemblage. For example, before González Echegaray and Barandiarán (1981) excavated in El Rascaño (with L. Straus) in 1974, most of the cultural deposits had already been removed by earlier excavations done by J. Carballo and L. Sierra in 1912 and H. Obermaier in 1921, leaving only a small remnant area in the rear of the cave vestibule available to modern excavation. The case is similar at Altamira cave (see Alcalde del Río 1906; Breuil and Obermaier 1935; Conkey 1980; Freeman and González Echegaray 2001; Straus 1975-1976). At El Mirón (most of which is not yet dug, unlike Altamira and El Rascaño), excavators have noted differences in artifact types in different areas of the capacious vestibule (Fontes et al. 2015; Straus et al. 2008). Following Fontes et al. (in press), this analysis assumes sample integrity—that the proportions of analytic nodules within each assemblage would remain consistent regardless of sample size—in order to make inter-site comparisons. However, it is important to reiterate Fontes et al.’s (in press) note that Last Glacial palimpsests compress evidence of prehistoric spatial organization: while archaeologists know about Magdalenian spatial complexity from exceptionally preserved sites such as La Garma, Etiolles, Verberie, Gönnersdorf, Oelknitz, Andernach, Champréveyres, and Monruz (see Arias et al. 2011; Audouze and Enloe 1997; Barandiarán et al. 1985; Bullinger et al. 2006; Gaudzinski-Windheuser 2015; Leesch 1997; Leesch et al. 2012; Leroi-Gourhan and Brézillon 1972; Street et al. 2012; Terberger 1997), this evidence can virtually disappear in the dense, at times meter thick Magdalenian residues recovered in cave settings. When remnant and/or spatially marginal cave areas are the only areas available to modern excavators, archaeological interpretations of these prehistoric
occupations are likewise limited based on which activities prehistoric hunter-gatherers carried out in the excavated locations.

(3) A third factor to consider is the sample sizes of analytic nodules, which differ in each assemblage examined in this case study. This variation could be the result of landscape variation and/or behavioral patterns or preferences: how abundant was the stone at its outcrop? How much time had elapsed since the stone was procured? Did foragers perceive a need for additional toolstone? Was the role of a toolstone primary or supplementary within the toolkit? These are just some questions that arise when archaeologists consider the relative quantities of lithic toolstones in assemblages (Andrefsky 1994; Bamforth 1986; Bamforth and Bleed 1997; Beck et al. 2002).

Following Fontes et al. (in press), this study assumes that raw material proportions within archaeological assemblages reflect the amounts of those materials that prehistoric hunter-gatherers had in their mobile toolkits when they occupied each site. This permits inter-site comparisons of toolstones based on their assemblage portions. This behavioral assumption is necessary to reconstruct LCM mobility from archaeological assemblages because it is the basis of the “distance-decay” principle—that a raw material will diminish in quantity within a mobile toolkit as groups move further from its source outcrop (Bamforth 1986). Like the first two assumptions, this factor also fuses what may have been many discrete actions into behavioral patterns and facilitates long-term reconstructions of human-technological-landscape interactions (Bailey 1983, 2007; Binford 1980; Fontes et al. in press; Straus 2013).

(4) Finally, this study assumes that hunter-gatherers were residentially mobile (following Fontes et al. in press) and exploited lithic toolstone outcrops located within
daily foraging radii. This assumption follows Binford’s (1979) assertion that lithic procurement was an embedded strategy wherein groups collected toolstones as part of their regular subsistence schedules instead of taking exclusive trips to raw material outcrops. In this scenario, once hunter-gatherers collected lithic materials, they conveyed them through foraging territories (following Amick 1996; Binford 1979; Cowan 1999; Fontes et al. in press; Goodyear 1989; Jones et al. 2003, 2012; but see also Bamforth 2002; Elston and Zeanah 2002; and Madsen 2007). As Fontes et al. (in press) demonstrate, LCM assemblages contain a diverse array of lithic toolstones that presumably correspond to unique outcrops. Using residential mobility and within-patch foraging frameworks, mobile toolkits included a variety of toolstones in various reduction phases that corresponded to: a) each material’s gradual reduction through use in daily tasks and b) the distance a group traveled from each material’s outcrop. Eventually, toolstones would lose their utility due to size reduction, be discarded, and then be replaced by another raw material from an outcrop located in the patch the hunter-gatherer group now occupied (Andrefsky 1994, 2009; Bamforth 1986; Beck et al. 2002; Shott 1986). Such within-patch foraging would leave patterned archaeological traces, assuming that raw materials were reduced at patterned rates based on their production efficiency, resulting in toolstone distribution in some areas of a habitual territory yet absence from others (Jones et al. 2003, 2012). Additionally, if lithic toolstones were only procured within patches as part of a residential mobility strategy, site to outcrop distance would have a neutral effect in lithic raw material choice. However, there are two potential exceptions to this rule:
(a) cases where two (or more) lithic sources are equidistant from a site and within
the same patch, in which case the model predicts that the material with the highest
production efficiency would be selected; or

(b) cases where two (or more) lithic sources had equal production efficiency, in
which case the preferred outcrop would be the one at a lesser distance (Hawkes and
O’Connell 1981; MacArthur and Pianka 1966; Smith 1983). Unfortunately, due to the
abundance of raw materials from unknown lithic outcrops in Cantabrian lithic
assemblages (see Fontes et al. in press), at this time it is not possible to address either of
these scenarios in detail here. Further archaeopetrographic studies (like that of Tarriño et
al. 2014) will help remedy this situation, expanding the corpus of comparative collections
and consequently improving archaeological understanding of prehistoric toolstone use in
the Vasco-Cantabrian region.

7. Results

7.1 Production Efficiency Summary

The lithic assemblage with the greatest production efficiency is from El Mirón
cave ($P=4,035,547$ mm; 38 analytic nodules), followed by El Juyo ($P=2,401,838$ mm; 32
analytic nodules), Altamira ($P=1,289,521$ mm; 45 analytic nodules), and El Rascaño
($P=1,113,634$ mm; 29 analytic nodules) (Table 1). The El Mirón and El Juyo
assemblages have the highest portions of bladelet production, 29% and 16%,
respectively; whereas both Altamira and El Rascaño have greater quantities of flakes
(90% and 84%, respectively) in their assemblages (Table 1). A summary of each analytic
nodule from the four sites is presented in Appendix A.
At Altamira, 90% of the lithic manufacture produced flakes; consequently, flake cutting edge is the greatest portion of the assemblage’s potential production efficiency (Table 2). While blades and bladelets were produced in equal measure in the Altamira assemblage, bladelets could produce more than two times the amount of cutting edge on average based on the model. This testifies to how efficiently LCM groups could exploit lithic toolstones by manufacturing bladelets. The flake, blade, and bladelet cutting edge ranges and standard deviations are comparable, which testify to variable analytic nodules in the Altamira assemblage that reflect the region’s heterogeneous lithology (Appendix A). Some of the variation in production efficiency identified in these assemblages also relates to small sample sizes, especially for non-conveyed toolstones (see Appendix A).

The El Juyo assemblage is composed of 74% flakes, 10% blades, and 16% bladelets. Despite being similar percentages of the assemblage, based on the model, blade reduction produced a modest average amount of cutting edge (5,541 mm) dwarfed by that that could be manufactured in bladelets (65,766 mm) (Table 2). Flake cutting edge is also overshadowed by bladelets by more than 3:1 (Table 2). However, the standard deviation for El Juyo bladelet cutting edge is quite large, which likely reflects some analytic nodules being used to manufacture blanks for diminutive “Juyo bladelets”, (possibly?) armatures made by marginal retouch on whole bladelets typically only 8 mm in length (Barandiarán et al. 1985). El Mirón Level 504, an assemblage that is similarly bladelet-oriented, indicates a production efficiency model similar to that of El Juyo: bladelets diminish the other blanks in potential cutting edge, 8:1 for blades and slightly over 2:1 for flakes. Finally, at El Rascaño, the assemblage production efficiency is similar to that of Altamira, though bladelets could produce only a slightly greater quantity of cutting edge
(Table 2). Although blades and bladelets are equal portions of the El Rascaño assemblage, bladelets contributed 4x the cutting edge to its production efficiency (Table 2). Together, these assemblages show that bladelets have a greater influence on potential production efficiency than other types of debitage.

7.2 Which Toolstones Were Most Efficient?

The greater the quantity of flake products in an analytic nodule, the lower the production efficiency of that nodule. Analytic nodules of toolstones that were used for bladelet production had the greatest potential production efficiency (Fig. 2). The greater the portion of bladelets in an analytic nodule, the more efficiently the toolstone was being used. Despite being a less efficient use of lithic toolstone, flakes were produced as part of nearly every analytic nodule examined in this case study (see Appendix A). LCM groups would have needed flakes for a variety of expedient and retouched tools—continuously retouched pieces, burins, endscrapers, notches, etc. These blanks are likely ubiquitous in lithic assemblages because they were flexible. Blades are generally ≤20% of analytic nodules (Fig. 2; Appendix A). Although standardized lithic products, they did not have the same influence on toolstone potential production efficiency that bladelets did (Fig. 2). Blades occur in small quantities in LCM lithic assemblages, likely as preparatory removals that gradually decreased in size, crossing the <2 cm bladelet boundary as core volumes were depleted (Fontes et al. in press). Bladelets are as standardized as blades, except on a smaller, thinner scale, permitting a greater number of microliths (and consequently, a greater quantity of cutting edge) to be produced from the same volume. Thus, the absence/presence/portion of bladelets in an analytic nodule had the greatest influence over its potential production efficiency. Additionally, a toolstone’s capacity for
Fig. 2. Potential Production Efficiency in Analytic Nodules based on portions of Flakes (bottom), Blades (middle), and Bladelets (top) in each.
Fig. 3. Flake, Blade, and Bladelet Potential Cutting Edge Produced in Analytic Nodules from Cantabrian Regional Flint Outcrops: Barrika (top), Llaranza (middle), and Sonabia (bottom).
bladelet production testifies to its overall high quality and homogeneity—it was fine grained enough to reliably produce standardized products. The production efficiency model proxies how efficiently each lithic raw material could be under the same volumetric constraints.

The three regional lithic raw materials—Barrika, Llaranza, and Sonabia—have very similar potential production efficiency (Fig. 3). Blades are small contributions to each of these analytic nodules, less than 10% of what was produced in all cases except for the Barrika analytic nodule from El Juyo (16%; Appendix A). Flakes range from between 60-90% of the analytic nodules from these three toolstones, consistently producing ~20,000 to 30,000 mm cutting edge. Bladelets produced in each analytic nodule yielded high potential cutting edge values, especially in the samples from El Juyo and El Mirón. Together, these samples demonstrate the potential that each of these toolstones had for bladelet production and the high quantities of cutting edge that could be produced when bladelets were manufactured.

The relationship between debitage products and potential production efficiency is well illustrated with Barrika toolstone (Appendix A). In the Altamira assemblage, Barrika toolstone was produced at rates of 85% for flakes, 8% for blades, and 7% for bladelets. At El Juyo, those rates were 58%, 16%, and 26% for flakes, blades, and bladelets, respectively. In El Mirón Level 504, bladelets were also a high portion of the Barrika analytic nodule, 33%, compared with 59% for flakes and 9% for bladelets. Finally, in the El Rascaño collection, 73% of the Barrika debitage were flakes, 15% blades, and only 12% were bladelets. Consequently, the quantities of cutting edge that could be produced by bladelet blanks at El Juyo and El Mirón were much greater—82,345 mm and 84,559
mm, respectively, than the 16,944 mm at Altamira and the 22,771 mm at El Rascaño. Thus, how LCM groups used lithic raw materials influenced the potential production efficiency of the raw material. Barrika toolstone could (and was used to) produce bladelets at high rates, which begs the question: why did LCM groups not always elect to reduce this raw material such that it would always yield its greatest potential? It is possible that the Altamira and El Rascaño assemblages, which were recovered from small and/or marginal areas within their respective cave vestibules, may not represent the range of lithic reduction behaviors that took place at each site. This difference could also relate to site function, i.e. that groups may have “geared up” at El Juyo and El Mirón and produced sufficient quantities of bladelets that they could transport them to sites like Altamira and El Rascaño, thereby limiting the quantities of these products that needed to be produced on site. While this point remains unresolved, that Cantabrian regional flysch flints could be used to efficiently manufacture bladelet products is clear. It should also be noted that for each of the geographically known raw materials discussed in this section, there is only a small sample of analytic nodules available for comparison—from only four sites. While it is apparent based on these samples that bladelet production corresponds to greater potential production efficiency values, a larger sample of Vasco-Cantabrian LCM sites is needed to assess these relationships in greater detail.

Extra-regional flints indicate patterns similar to those of Cantabrian regional flints: both Treviño and Urbasa have higher potential cutting edge values for bladelets than for other debitage products (Figs. 3 and 4). Blades comprised small portions of these analytic nodules, and though flakes varied in their portions, they still had lower potential cutting edge values compared to bladelets. However, Treviño and Urbasa were much
more efficient toolstones, especially in bladelet production, than any of the Cantabrian regional flints (Fig. 5). Barrika, Llaranza, and Sonabia are approximate equals in the potential cutting edge that could be produced in bladelet manufacture (a quality that may relate to the flints originating in similarly aged [Cretaceous] geologic formations). When
Fig. 5. Potential Cutting Edge Produced by Bladelet products in Analytic Nodules from Geographically Known Outcrops

bladelets make up 33\% of a Barrika analytic nodule, the amount of potential cutting edge is 84,559 mm. In contrast, for Urbasa (also at 33\%), this value is 191,250 mm (although this is based on a small sample), and for Treviño, (34\%) it is 154,690 mm. Treviño and Urbasa flints could produce nearly twice as much cutting edge in bladelet production than Cantabrian regional flysch flints. Bladelets were an essential component of LCM lithic toolkits—a key contribution to composite hunting weapons systems. Consequently, LCM hunter-gatherers needed to be able to produce large quantities of bladelet blanks to create replaceable lithic insets. The high potential production efficiency of the extra-regional flints offers an explanation for why groups would desire these distant (c. 200 km afield depending on the route) toolstones. Furthermore, it contextualizes other aspects of LCM adaptive strategies that are discussed in greater detail below: toolstone conveyance;
procurement of local stones to hedge against depleting highly efficient raw materials; and maintaining lithic acquisition systems via mobility strategies or social networks.

While this discussion has focused on flints from geographically known outcrops, other lithic raw materials were important components of LCM assemblages, including quartzites, mudstones, quartzes, and limestones (Table 3). All non-flint toolstones have lower potential production efficiency values relative to the flints. These materials, which appear in small quantities in LCM lithic assemblages, also show little to no evidence of bladelet reduction (Table 3; Appendix A). These stones, which were probably collected from local riverbeds or outcrops (see Fontes et al. in press; Straus 1992; Straus et al. 2008), were primarily used for flake production, probably as an expedient component of the overall technological system that was focused on using less efficient local stones to eschew those that were most efficient for more wasteful flake manufacture. All of the flints had three to four times more potential production efficiency as the other kinds of lithic toolstones (Table 3). Flints from geographically known outcrops (e.g. Barrika, Treviño) were similarly efficient to other conveyed flints, indicating that if LCM groups transported stones in mobile toolkits, they preferred those that were highly efficient. Local flints, which occur in smaller sample sizes in LCM lithic assemblages (see Appendix A), were generally used for flake production. For example, F41 at El Juyo was used to produce flakes at a rate of 72%; 78% of the debitage made from F48 at the Altamira were flakes; and 77% of the F55 analytic nodule at El Mirón testifies to flake manufacture (Appendix A). Local flints were probably procured as a more efficient component of the same expedient organizational strategy that LCM groups used to acquire mudstones and quartzites.
7.3 How did Toolstone Efficiency Influence Raw Material Management?

Bladelet production influenced LCM mobile toolkit composition and management strategies. In the Altamira assemblage, there are 14 toolstones that were used to manufacture bladelet products. Ten of these materials were conveyed (71%): six stones among four sites, two stones among three sites, and two stones between Altamira and one other site in this four site sample. An additional 34 toolstones were not used for bladelet production at Altamira. Only 13 of these materials were conveyed: six between two sites and two among three and four sites, respectively. At El Juyo, 18 lithic raw materials were used to produce bladelets, and 13 of these (72%) were conveyed to other sites. Eight toolstones were transported to among four sites, three stones among three sites, and two materials between two sites. There are only 12 toolstones that were not used to produce bladelets, and only three of these were conveyed to other sites: two materials to between El Juyo and another site, and one material among all four sites. The El Mirón assemblage shows a similar trend. There are 26 toolstones in this sample that were used to produce bladelets. 15 of these stones were conveyed (58%). Nine of these materials have been identified in all four Cantabrian sites sampled here; the remaining six were evenly split, with three circulated among three sites and two conveyed between two sites. There are only 15 raw materials that were not used to produce bladelets. Two of these stones were conveyed, both between El Mirón and one other site. Finally, there were 15 raw materials in the El Rascaño assemblage that were used for bladelet manufacture. Twelve of these (80%) were transported through the Cantabrian region: seven among four sites; three among three sites; and two between El Rascaño and another site. The assemblage had 16 lithic toolstones that were not used for bladelet manufacture; seven were conveyed in
mobile toolkits. Four of these are found at El Rascaño and one other site. One material is identified in three assemblages, and two materials were recovered at all four sites. All four sites show the same trend: those toolstones that were used for bladelet production were more likely to be conveyed among Cantabrian sites. Additionally, lithic raw materials used to manufacture bladelets were conveyed to more sites than those stones that were not used for bladelets. This indicates that the raw materials that LCM hunter-gatherers used to produce bladelets influenced these groups’ lithic toolkit management systems: which stones they chose to safeguard in mobile toolkits and which stones supplemented that transportable lithic resource base. Supplementing the toolkit with less efficient toolstones that were primarily used for flake reduction (see Appendix A) and transported between sites on a limited basis would have been an optimal organizational strategy because it would have allowed groups to lessen lithic procurement costs and maximize the benefits of highly efficient toolstones.

Evaluations of specific conveyance trajectories proposed by Fontes et al. (in press) also support this toolkit management hypothesis (Table 5). Those toolstones conveyed between two or three sites have small analytic nodule sample sizes (see Appendix A). Many of these stones confirm the aforementioned trend of limited inter-site conveyance for toolstones used predominately for flake manufacture. However, bladelets do occur in appreciable amounts in some analytic nodules that were transported among three sites, for example F29 at El Juyo (27%, n=26) and F66 at El Juyo (19%, n=84). Toolstones conveyed among all four sites have larger sample sizes. As observed previously, bladelets are a major component of each of these analytic nodules, especially at El Juyo and El Mirón (where they are 20-30% of the debitage produced). Fontes et al.
(in press) noted that shifting environmental zones appears as a pattern in lithic conveyance. It is possible that bladelet manufacture (i.e., “gearing up”) occurred more often at some sites (El Juyo and El Mirón) because of where these sites probably stood within the groups’ overall settlement system as it related to subsistence and toolstone acquisition schedules. LCM groups would have needed to retain access to highly efficient toolstones that they could use to produce bladelets in order to ensure that the hunting weaponry component of their mobile toolkits was well stocked. LCM hunter-gatherers made investments in specific stones that could reliably produce bladelet products (e.g. Barrika, Llaranza, Urbasa). The potential production efficiency of lithic raw materials related not only to which products LCM groups could manufacture, but how they would later manage these stones after they acquired them.

8. Lower Magdalenian Adaptive Systems

The results of the production efficiency analysis indicate that LCM groups likely sought out highly efficient toolstones for bladelet production. These highly efficient stones were managed as part of mobile toolkits and gradually reduced as groups traversed their territory (Fontes et al. in press). As groups circulated across the landscape, they moved within local patches where they procured less efficient toolstones that they reduced at their camps for basic tasks that primarily required flake blanks. Thus, groups were able to hedge against depleting their highest quality toolstones (Fontes et al. in press). These less efficient toolstones were generally not conveyed among Cantabrian sites. This balancing act indicates that LCM groups anticipated toolstone needs and consequently planned their mobility, toolstone provisioning, and toolkit strategies to cope with an inconsistent regional lithology (Fig. 6). What remains ambiguous is how LCM
Fig. 6. Relationships Among Hunter-Gatherer Mobility, Toolstone Production Efficiency, and Toolkit Management

groups procured lithic raw materials: by moving directly to toolstone outcrops or via exchanges with other groups who had local access to these resources.

8.1 Procurement via Direct Access

Fontes et al. (in press) propose that LCM hunter-gatherers formed an economically well-defined regional band based on similarities in lithic raw materials identified at Cantabrian sites. These groups may have traversed a large territory that extended from eastern Asturias to western Navarra where the Treviño and Urbasa lithic outcrops are located. Fontes et al. (in press) suggest that the territory south of the Cantabrian Cordillera may have only been used seasonally, when groups could have crossed mountain passes without significant snow cover (Clark 1981; Pokines 2001). A residential mobility system within a large territory would have offered LCM groups the ability to efficiently exploit the patchy environment in northern Spain by expanding their
resource base. These groups may have seasonally or annually occupied smaller portions of a long-term habitual range that fluctuated in balance with available resources (Binford 1982, 1983; Kelly 1992). Seasonal/annual shifts in land tenure within a habitual range would have helped LCM groups respond to resource stress through movement. As groups moved to the western Navarra section of this territory, they would have been able to procure highly efficient stones (Treviño and Urbasa flints) and later convey these through other sections of their territory (Fontes et al. in press). It is possible that LCM groups chose to expand their territory into this zone because the raw materials were highly productive. Additionally, LCM groups may have met up with other groups in this zone, acquiring exotic toolstones like Bidache and Chalosse at these meetings (Fontes et al. in press).

Fontes et al. (in press) suggest that LCM group movement would have had consequences for how groups maintained their mobile lithic toolkits. First, Cantabrian lithic assemblages indicate that LCM groups managed multiple toolstones concurrently, searching for local raw materials to supplement those that were conveyed (Fontes et al. in press). The production efficiency model indicates that those materials that were conveyed were overwhelmingly of a higher quality and used for bladelet production, while locally procured materials that were less efficient were reduced at single sites, probably to defray the costs of using high quality stones. Conveyed lithic toolstones indicate that LCM groups had sub-regional territories where they moved between environmental zones, testifying to how environmental patchiness influenced LCM adaptive mobility strategies (Fontes et al. in press). Thus, raw material production efficiency may have influenced
LCM toolkit management on several scales: how broadly groups cast their land tenure; what materials they procured locally; and what stones they conveyed.

Although lithic toolstones are infrequently discussed as driving factors for movement (rising/falling/shifting faunal populations are often considered prime movers), if hunter-gatherers were embedding lithic procurement in their subsistence forays (Binford 1979), the choice to exploit resource patches near highly productive lithic toolstones would have allowed LCM groups to effectively “kill two birds with one stone”. First, moving to resource patches in western Navarra would have allowed patches along the Cantabrian coast to recover their biomass (which may have been necessary if people were regularly using mass slaughter techniques to secure ungulate resources [Freeman 1973]). At the same time, the Treviño and Urbasa toolstones were extraordinarily efficient for bladelet production, which, when transported in mobile toolkits, would have provided groups blanks that they could use for weapon armatures as they circulated the rest of their territory.

There are some ethnographic cases of hunter-gatherers making similar territorial decisions in areas with low primary biomass. First, the Baffinland Inuit, who make an average of 60 residential moves per year at an average distance of 12 km within a c. 25,000 km\(^2\) area (Hantzsch 1977; Kelly 2007). Another more common example are the Nunamiut, who average ten residential moves per year at an average distance of 69.5 km in an area ranging from 5,200 to 20,500 km\(^2\) (Amsden 1977; Binford 1978; Kelly 2007). (In contrast, the Dobe Ju/'hoansi [!Kung San] of the African Kalahari Desert move only six times per year, 23.6 km on average, within a smaller 260-2,500 km\(^2\) area [Hitchcock 1987a, 1987b; Lee 1979]. Their land tenure and exchange systems are discussed in more
detail in the next section.) If LCM groups made residential moves following the Baffinland Inuit or Nunamiut pattern, groups would have made approximately one third of their annual mobility to travel the c. 200 km from central Cantabria to the Urbasa outcrop, presumably the eastern bound of their habitual territory. Thus, it is possible that LCM groups moved within very large territories. Additionally, the Arctic ethnographic cases have also been applied to the French Magdalenian archaeological record to understand aspects of group mobility and spatial organization in this region (see Audouze 2006, 2007; Audouze and Beyries 2007). However, French Magdalenian groups were serial specialists focused on following ungulate herds; Vasco-Cantabrian groups were faced with a fundamentally different, high relief, coastal, and patchier environment that necessitated different adaptive strategies. Thus, while LCM hunter-gatherers may have used a residential mobility system to adapt to the region’s environmental complexity, it would not have been the only available adaptive solution.

8.2 Procurement via Exchange

The relationships that modern foragers have with mobility, land tenure, and intra- and inter-group exchange are complex ones (Kelly 2007). Presumably, prehistoric hunter-gatherers had equally complex relationships with their landscapes. Ethnographic studies can help contextualize ways that prehistoric groups could have organized these systems. A group’s land tenure (what archaeologists might term a “territory”) governs what resources individuals or groups had access to and how they share access rights to those resources (Kelly 2007). Ethnographic research has shown that modern hunter-gatherers are not laissez-faire about how tracts of land are used: what territories people have access to reflect the decisions of individuals and often how those individuals relate to others
Individuals have connections to land that shift through social, political, and ecological processes (Kelly 2007). Thus, as opposed to archaeological definitions of landscapes that are often rigidly geographically defined (i.e., Vasco-Cantabria, the Ebro Basin, etc.), ethnographic research demonstrates that human-land relationships are both social and flexible (Kelly 2007; Lee 1979; Wiessner 1982). Additionally, how people move within their territories is another individual behavior (though archaeologists often discuss mobility as a group activity). Studies of modern foragers demonstrate that people can move long and short distances, alone or together, frequently or infrequently, and on daily, seasonal, or annual bases (Kelly 2007). Ethnographic research proposes significant connections between land tenure and ideology: that groups socially constructed their shared identities and inter-personal relationships, relating individuals to each other and to tracts of land (Lee 1979). Land tenure has important archaeological implications because it effectively “maps” what resources groups would have had access to. In the Vasco-Cantabrian Lower Magdalenian case study, this “ethnic” band may have comprised many groups with individually defined, adjacent land areas that extended from eastern Asturias to western Navarra (González Morales and Straus 2009). LCM groups may have used a kind of “down-the-line” exchange system to circulate toolstones throughout these land areas. The sections that follow describe the Ju/'hoansi (a !Kung San group) from the Dobe area of the Kalahari Desert in southern Africa in order to illustrate how hunter-gatherers can establish land tenure systems and how materials exchanges can occur within those systems.

The Dobe Ju/'hoansi (!Kung San), who live in the Kalahari Desert in Africa, maintain a heritable land tenure system called n!ore. Individuals possess n!ore, which
range from 300-600 km² (though this can vary annually) and are centered on watering holes (Lee 1979). A core group exploits the resources in each n!ore. To access a resource in another groups’ n!ore, permission must be obtained from the individuals who occupy it (Kelly 2007; Lee 1979; Wiessner 1982). Thus, access to n!ore is secured through social relationships, which originate through fictive kinship ties or trading partnerships. Dobe Ju/'hoansi kinship ties are based on names, recycled from generation to generation, which affirm social obligations to n!ore land tracts (Kelly 2007; Lee 1979; Wiessner 1982).

Trade partnerships are part of a network called hxaro that connects the Dobe Ju/'hoansi with other !Kung San groups. Dobe Ju/'hoansi individuals establish social relationships with others and trade items like arrows, blankets, clothing, pots, and ostrich eggshell beads (Kelly 2007). Most trading partners live within 40 km of each other, although some relationships have been documented between individuals as far as 200 km away (Wiessner 1982). Though no one gains materially from hxaro exchange (gifts are kept for up to two years, then passed to another trade partner), the social connections provide a risk buffer in times when resources fluctuate (Wiessner 1982). In these moments, Dobe Ju/'hoansi individuals will travel intentionally to visit their trade partners to gain access to resources. This is a common pattern in hunter-gatherer groups: to use a social safety net in times of need (Spielmann 1986).

The Dobe Ju/'hoansi provide an interesting comparative case that can be used to interpret the LCM archaeological record. If LCM groups had n!ore-type land tracts (akin to the systems envisioned by Straus 1986 or Utrilla 1981), the local lithic toolstone provisioning that Fontes et al. (in press) document could represent groups utilizing raw materials within these zones. These less efficient local stones may have been used to
hedge against wasting highly efficient raw materials as groups waited for their next exchange opportunity, where they presumably acquired toolstones with the greatest potential production efficiency (i.e., Treviño and Urbasa flints). In this scenario, the sub-regional territories that Fontes et al. (in press) have modeled could have related to groups conveying toolstone within their n!ore-type land tracts or between these areas to exploit different kinds of comestible resources and make/maintain social connections with other groups living in adjacent land areas. Archaeologists have noted that n!ore-like land areas may have existed in Vasco-Cantabria, where similar arrays of sites (i.e., related to exploiting particular resource niches and art sanctuaries) have been identified in major river valleys that form natural geographic boundaries (see Utrilla 1981). It is possible that a succession of small valley-territories subdivided the economic zone that extended from eastern Asturias to western Navarra. Thus, the economic zone may represent the territory of a distinct, regional Magdalenian “ethnic” group, identified archaeologically by portable art items such as engraved scapulae, but which included numerous, interacting local bands who shared a distinct, socially constructed identity that could have been reinforced through exchange relationships (González Morales and Straus 2009; Schwendler 2012). The hxaro exchange network provides an ethnographic context that testifies to hunter-gatherers maintaining social relationships and trade partnerships over an equally large geographic scale (Wiessner 1982). Finally, Fontes et al. (in press) proposed that LCM groups maintained inter-territorial exchange networks where they obtained exotic flints from southern France (small amounts of Bidache and Chalosse). Individuals who lived at the eastern boundary of the LCM economic territory (i.e., western Navarra), may have established trade partnerships for lithic toolstones with
members of Magdalenian bands who occupied what is now the Basque country (in
northern Spain/southern France). These inter-band contacts would not have only brought
small quantities of high-quality toolstones into the LCM economic zone, but would have
maintained LCM groups’ relationship to the greater “Magdalenian world”. This broad
connection has been documented at El Mirón cave, where excavators recovered an atl-atl
hook (spearthrower) and a perforated red deer incisor (identified by J.M. Geiling) that are
nearly identical to similar artifacts recovered at the penecontemporaneous Roc-de-
Marcamps (Gironde, near Bordeaux, France) and Le Placard (Charente, France)
(Cattelain 2004; González Morales and Straus 2009; Kuntz et al. 2015). In sum, it is as
plausible that LCM groups acquired lithic toolstones via exchange networks as it is that
they acquired them through direct outcrop access. In either case, LCM groups would
have managed their lithic economies, including their mobile toolkits, on local, regional,
and “global” scales.

8.3 Economic Insurance or Social Insurance?

LCM groups could have obtained lithic raw materials through both direct access
and exchange; these two systems are not mutually exclusive. Each strategy is an equally
adaptive approach that LCM hunter-gatherers could have used to solve problems related
to environmental variance (e.g., in lithology, comestible resources, etc.) and resource
stress. In the first case, LCM hunter-gatherer groups would have managed risk through
mobility strategies within territories, expanding and contracting their resource patch base.
Maintaining flexible territories in this way would have been an adaptive measure because
it would have permitted groups to cope with resource fluctuations—effectively, groups
would have been regulating local comestible resource population densities in relation to
their own resource use, preventing over-exploitation through relocation to a different resource patch. In the second case, social ties would have formed groups’ security through information and resource flow, in turn helping groups avoid over-exploitation (Lee 1979; Peterson 1975, 1978; Peterson and Long 1986; Wiessner 1977, 1982). Not only would LCM groups have been able to acquire raw materials when they moved to exchange locations, but they would have learned about environmental conditions in adjacent areas (Whallon 2006). Inter-group reciprocity is one way that groups can establish social ties with individuals who can provide assistance in times of need, consequently, maintaining exchange partnerships would have been correlated to the temporal (i.e., seasonal, annual) and spatial parameters of resource fluctuations (Cashdan 1983; Kelly 2007; Smith 1988). However, it is important to note that if LCM groups did depend on exchanges to acquire lithic raw materials, they would have somehow needed to ensure that these networks did not collapse, otherwise they would have faced significant risks if their access to resources diminished (this is often why archaeologists favor high residential mobility/large territory scenarios [see Jones et al. 2003]). Exactly how LCM groups would have maintained these systems (through [fictive] kinship? ideology/ritual? exchange of material goods? partners?), is unknown; but, the Magdalenian story is one of growth, of gradual expansion across Europe following the Last Glacial Maximum (Otte 2012; Straus 2013). That is to say, if LCM groups did depend on socio-cultural networks for resources, whatever ties they were based on were strong enough that they withstood cultural, technological, and environmental change until the arrival of the Holocene.
8.4 Limitations in the Vasco-Cantabrian Archaeological Record

While both of the procurement scenarios discussed in this paper can aid in anthropological interpretations of LCM economic systems, there are several aspects of these proposals that remain unresolved based on the archaeological record in this region. First, archaeologists have not yet identified Magdalenian-age sites in Alava (but see Utrilla et al.’s [2015] description of Abauntz cave, which while in Navarra is not located at the Treviño or Urbasa flint outcrops). While new archaeological sites are discovered annually in northern Spain, this is a notable gap in the archaeological record that is at least in part due to formation processes (i.e., cave sites with well-preserved and datable occupations are typical on the Vasco-Cantabrian coast yet uncommon south of the Cantabrian Cordillera) and sampling that has historically focused on the coastal region. If groups did not exploit this territory on a regular basis, it is still possible that the Treviño and Urbasa outcrops were accessed by individuals or small groups who made logistical trips to the outcrops from the easternmost LCM territories (perhaps located in the Río Asón drainage, where the easternmost engraved scapulae have been recovered from El Mirón cave [González Morales and Straus 2009]). Second, if any lithic raw materials were exchanged among LCM groups (a reasonable assumption based on the small quantities of Bidache and Chalosse toolstones in Cantabrian assemblages), they were expendable resources, unlike the items exchanged by Dobe Ju’/hoansi individuals in the hxaro system, which were passed on such that no individual made material gains. The highly efficient lithic toolstones identified in LCM assemblages all come from eastern outcrops—Treviño, Urbasa, Bidache, Chalosse—which begs the question: which items did western LCM groups pass eastward in exchange for these lithic raw materials?
Perhaps “items” could have taken the form of seasonal resource access permissions (perhaps eastern groups could winter on a more favorable coastal zone?), art objects, mates, or perishable items like clothing or comestibles. Finally, both procurement scenarios make fundamental assumptions about primary biomass and population size. The first interpretation, procurement via direct access coupled with a large territory, assumes a low biomass and a relatively low population size based on ethnographic correlates (Binford 1979; Kelly 2007). The second scenario, procurement via exchange, assumes a high enough biomass that LCM groups could have supported their populations within (perhaps) a valley territory, and a high enough population that groups in adjacent valley territories could interact on a regular basis. It is also possible that both human and animal population sizes shifted throughout the LCM, corresponding to gradual climatic amelioration. Unfortunately, the archaeological record provides only coarse proxies for these variables.

9. Conclusion

LCM hunter-gatherer groups could have procured their lithic raw materials directly at source outcrops, through exchanges with other groups, or both. Each procurement scenario can be supported through ethnographic correlations and the archaeological record. The production efficiency analysis used in this paper testifies to the significance of bladelet manufacture in LCM assemblages, and consequently, to these hunter-gatherers’ landscape level mobility and toolkit strategies. That LCM groups needed bladelets for composite weapons systems could have had an important influence on their adaptive strategies: they may have sought and moved to (individuals or outcrops with) highly efficient toolstones that they then used to manufacture bladelet blanks. They
later conveyed these materials among the sites they occupied. When residing at their residential bases, they may have elected less efficient toolstones within their catchment zones to ensure that they did not deplete the highest quality materials. Bladelet manufacture influenced aspects of LCM adaptive strategies, especially the procurement of highly efficient toolstones (and the corresponding mobility, territory, and perhaps social maintenance this would have required), and the management of toolkits.

Finally, the production efficiency model, a heuristic that compares the amount of cutting edge that could be produced from standard volumes based on archaeological correlates, is an indirect method that archaeologists can use to quantify lithic raw material quality. The model is highly replicable because it is based on measurements that are standard in lithic analysis: debitage length, width, and thickness. The model can help archaeologists understand how efficiently prehistoric groups manufactured different kinds of debitage products, and is broadly applicable in archaeological case studies. For example, archaeologists could apply this model to understand variation in individual flintknappers in cases with refitted nodules with known volumes. Archaeologists could also use this model to understand variation in lithic products manufactured using different kinds of toolstones (i.e., obsidian, flint, basalt, etc.) in any cases where raw materials are heterogeneous enough to be distinguished (or likewise, could be geochemically sourced). When applied to landscape-level case studies like the one presented here, the production efficiency model can help contextualize prehistoric adaptive strategies related to lithic raw material management.
Acknowledgements

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Table 1. Production Efficiency in Cantabrian Lithic Assemblages.
Production efficiency (P) is measured in millimeters. Flake, blade, and bladelet portions of the debitage assemblage are conveyed as percentages.

<table>
<thead>
<tr>
<th>Site</th>
<th>Sample Size</th>
<th>P</th>
<th>Flake Portion</th>
<th>Blade Portion</th>
<th>Bladelet Portion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altamira</td>
<td>2,346</td>
<td>1,289,521</td>
<td>90</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>El Juyo</td>
<td>1,846</td>
<td>2,401,838</td>
<td>74</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>El Mirón</td>
<td>4,973</td>
<td>4,035,547</td>
<td>63</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>El Rascaño</td>
<td>1,722</td>
<td>1,113,634</td>
<td>84</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 2. Variation in Cutting Edge Produced from Debitage Products at Four Cantabrian Sites
Variation in cutting edges for flakes (e_f), blades (e_b), and bladelets (e_l); all values are in millimeters.

<table>
<thead>
<tr>
<th>Site</th>
<th>e_f Average</th>
<th>e_b Minimum</th>
<th>e_b Maximum</th>
<th>e_b Standard Deviation</th>
<th>e_l Average</th>
<th>e_l Minimum</th>
<th>e_l Maximum</th>
<th>e_l Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altamira</td>
<td>20,479</td>
<td>5,852</td>
<td>13,910</td>
<td>8,436</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El Juyo</td>
<td>18,103</td>
<td>65,766</td>
<td>664</td>
<td>4,432</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El Mirón</td>
<td>26,381</td>
<td>64,044</td>
<td>5,831</td>
<td>45,115</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El Rascaño</td>
<td>19,033</td>
<td>22,042</td>
<td>4,980</td>
<td>17,180</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Average Production Efficiency based on Lithic Toolstone Type

*All samples of quartzes and calcites include <10 debitage, making this result dubious. The portions of each debitage product type are listed as percent ranges for each raw material.

<table>
<thead>
<tr>
<th>Material Type</th>
<th>P</th>
<th>Flakes</th>
<th>Blades</th>
<th>Bladelets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographically Known Stones</td>
<td>86,781</td>
<td>46-100</td>
<td>3-30</td>
<td>4-34</td>
</tr>
<tr>
<td>Conveyed Flints</td>
<td>87,931</td>
<td>25-100</td>
<td>2-17</td>
<td>2-75</td>
</tr>
<tr>
<td>“Local” Flints</td>
<td>66,991</td>
<td>25-100</td>
<td>2-100</td>
<td>3-100</td>
</tr>
<tr>
<td>Quartzites</td>
<td>19,009</td>
<td>50-100</td>
<td>3-50</td>
<td>2-6</td>
</tr>
<tr>
<td>Mudstones</td>
<td>11,916</td>
<td>100</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Limestone</td>
<td>17,989</td>
<td>50-100</td>
<td>50</td>
<td>--</td>
</tr>
<tr>
<td>Quartzes &amp; Calcites</td>
<td>111,363*</td>
<td>67-100</td>
<td>33</td>
<td>--</td>
</tr>
<tr>
<td>Other Stones</td>
<td>20,975</td>
<td>90-100</td>
<td>3-9</td>
<td>2-10</td>
</tr>
<tr>
<td>Unknown Stones</td>
<td>11,177</td>
<td>75-100</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Lithic Manufacture and Conveyance Summary at Four Cantabrian Sites.

Lithic products and product combinations are abbreviated as follows: flakes (F); flakes and blades (FB); flakes and bladelets (FL); flakes, blades, and bladelets (FBL); blades (B), and bladelets (L). The number of raw materials used to manufacture each group of products is listed, by site. The parenthetical value is the number of materials in each grouping that were conveyed to at least one other Cantabrian site. *One of these materials is Chalosse, which doesn’t appear at another Cantabrian site in this sample, but whose outcrop is located in southwest France. This material may have arrived in the El Juyo assemblage via inter-group trade, see Fontes et al. in press for further explanation.

<table>
<thead>
<tr>
<th>Site</th>
<th>F</th>
<th>FB</th>
<th>FL</th>
<th>FBL</th>
<th>BL</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altamira</td>
<td>25 (10)</td>
<td>9 (4)</td>
<td>3 (1)</td>
<td>10 (9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>El Juyo</td>
<td>8 (2)</td>
<td>2 (1)</td>
<td>6 (4)</td>
<td>12 (9)</td>
<td>2 (0)</td>
<td>2 (0*)</td>
</tr>
<tr>
<td>El Mirón</td>
<td>13 (2)</td>
<td>2 (0)</td>
<td>6 (4)</td>
<td>20 (11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>El Rascaño</td>
<td>13 (5)</td>
<td>3 (2)</td>
<td>4 (1)</td>
<td>11 (11)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5. Average Production Efficiency and Lithic Toolstone Conveyance in Cantabria

Raw materials are listed in the order that they may have been conveyed based on models made by Fontes et al. (in press). Toolstones are listed by name or reference number following the same system used in Table 2, with sites abbreviated following underscores as follows: Altamira (_A), El Juyo (_J), El Mirón (_M), and El Rascaño (_R). Average production efficiency \( P \) for each analytic nodule is noted in millimeters. The rates of flake \( (r_f) \), blade \( (r_b) \), and bladelet \( (r_l) \) production in each analytic nodule are noted as percents. Weight \( (Wt.) \) values for analytic nodules are from Fontes et al. (in press).

<table>
<thead>
<tr>
<th>Two Site Trajectories</th>
<th>Toolstone</th>
<th>( P )</th>
<th>( r_f )</th>
<th>( r_b )</th>
<th>( r_l )</th>
<th>Wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altamira-El Juyo</td>
<td>QZ9_A</td>
<td>35,341</td>
<td>88</td>
<td>6</td>
<td>6</td>
<td>52.2</td>
</tr>
<tr>
<td></td>
<td>QZ9_J</td>
<td>6,830</td>
<td>50</td>
<td>50</td>
<td>--</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td>U6_A</td>
<td>6,186</td>
<td>100</td>
<td>--</td>
<td>--</td>
<td>295.1</td>
</tr>
<tr>
<td></td>
<td>U6_J</td>
<td>4,963</td>
<td>100</td>
<td>--</td>
<td>--</td>
<td>30.9</td>
</tr>
<tr>
<td>Altamira-El Mirón</td>
<td>L1_A</td>
<td>5,658</td>
<td>100</td>
<td>--</td>
<td>--</td>
<td>22.7</td>
</tr>
<tr>
<td></td>
<td>L1_M</td>
<td>6,550</td>
<td>50</td>
<td>--</td>
<td>50</td>
<td>11.2</td>
</tr>
<tr>
<td>Altamira-El Rascaño</td>
<td>F20_A</td>
<td>52,597</td>
<td>78</td>
<td>10</td>
<td>12</td>
<td>183.3</td>
</tr>
<tr>
<td></td>
<td>F20_R</td>
<td>22,964</td>
<td>84</td>
<td>16</td>
<td>--</td>
<td>100.5</td>
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Appendix A. Production Efficiency for Analytic Nodules from Four Cantabrian Sites

Geographically known raw materials are abbreviated as follows: Barrika (BAR), Bidache (BID), Chalosse (CHAL), Llaranza (LLAR), Sonabia (SON), Treviño (TREV), and Urbasa (URB). Geographically unknown raw materials are identified (i.e., F10) by raw material group and number in the reference system Fontes created for the Vasco-Cantabrian region, as follows: flints (F), limestones (L), mudstones (M), other materials (O), quartz and calcite (QC), quartzite (QZ), and unknown stone (U). Group F flints (abbreviated as GRPF) represent five visually distinct raw materials that are often found together on single artifacts; these likely originate from a highly variable outcrop. Archaeological sites are identified for each analytic nodule listed using an underscore, as follows: Altamira (_A), El Juyo (_J), El Mirón (_M), and El Rascaño (_R). Flake, blade, and bladelet production rates are referred to using shorthand from Equation 5.1.2: \( r_f \) for flakes, \( r_b \) for blades, and \( r_l \) for bladelets. The same shorthand is used for cutting edge values following Equation 5.1.5, where cutting edge is expressed as \( e_f \) for flakes, \( e_b \) for blades, and \( e_l \) for bladelets, and production efficiency is expressed as \( P \). Reduction stages are taken from Fontes et al. (in press), and stages are abbreviated as follows: all stages (A), early stage (E), mid-stage (M), and late stage (L). Some analytic nodules indicate multiple reduction stages, and in these cases two letters may be used as in "ML" for mid- to late-stage reduction. Conveyance is indicated by the number of sites (2-4, out of the four sampled here) where that raw material has been identified. Analytic nodules identified with "--*" indicate that there were insufficient data to calculate production efficiency. Conveyance values with † indicate that there was insufficient data to calculate \( P \) for the other site.

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Chapter 6: Conclusion

This dissertation presented four case studies that assessed how hunter-gatherers adapted their technological systems to environmental complexity during the early Magdalenian period of the Late Last Glacial. Three major themes link these case studies together: mobility, spatial organization (within sites and/or landscapes), and economic patterns (i.e., toolkit maintenance and management). These themes are discussed below in the context of the major conclusions presented in each case study.

1. Mobility and Spatial Organization

The Initial Magdalenian case study includes discussion of hunter-gatherer spatial organization, economic patterns, and mobility. Spatial organization was addressed in two different ways in Chapter 2. First, on an intra-site level, spatial analysis suggests three major things: (1) that the site had patterned activity areas in the outer and inner cave vestibule; (2) that occupations could have been intermittent or continuous in different areas of the cave; and (3) that the occupations has a similar character through time. Second, mobility models address groups’ spatial organization on the eastern Vasco-Cantabrian landscape. The Initial Magdalenian mobility models in Chapter 2 suggest that: (1) Initial Magdalenian land use was dynamic, perhaps representing the behaviors of people who were in flux due to changing environments at the end of the Last Glacial Maximum; (2) Initial Magdalenian groups considered raw material quality as they formed their toolkits and (3) designed those toolkits to balance long and short term needs; and (4) their territorial shifting may have been related to environmental and/or social needs.
Chapter 3 does not focus on LCM group movements, except to say that raw materials come from outcrops located a moderate distance (Barrika, 50-70 km) from El Mirón cave and that there is a general lack of primary decortication flakes, which may indicate that groups prepared cores elsewhere before transporting them. Chapters 2, 4, and 5 are more landscape focused than Chapter 3, however, Chapter 3 conveys the characteristics and integrity of the El Mirón sample that is further examined in Chapters 4 and 5. The Chapter 3 case study makes extensive intra-site spatial comparisons, including of lithic artifact to human remains distribution in Level 504 and of lithic tools and debris deposited throughout the El Mirón cave vestibule. These spatial analyses show that the lithic artifacts were deposited to the south of the human remains and demonstrate that the LCM occupations in El Mirón cave extended the length of the site’s vestibule.

The third case study (Chapter 4) is concerned with how LCM groups organized themselves and their lithic technology across the Vasco-Cantabrian landscape and assesses this issue based on lithic raw material conveyance among four sites in central sector of Cantabria province. This analysis indicates that LCM mobility took place within a large economic zone. Groups may have used seasonal transhumance strategies to expand and contract their territories within this zone to adapt to local environmental circumstances. At the sub-regional level, lithic conveyance indicates that shifting environmental zones was an important aspect of LCM settlement systems. This study proposes that LCM groups may have organized and maintained several interlocking, scalar mobility patterns: site catchments, sub-regional territories, habitual territories, and inter-territorial (exchange) networks. This case study demonstrates that mobility was an LCM adaptation to environmental complexity and that groups provisioned their toolkits
to coincide with these movements and anticipate daily tasks as they traversed the Vasco-Cantabrian region.

Finally, the results of the case study presented in Chapter 5 echo those of Chapter 4, but provide further context about LCM economic systems. Based on a toolstone production efficiency model, highly efficient toolstones that were used to produce bladelets were most likely to be conveyed among Cantabrian sites. Locally procured raw materials were less efficient and were also less likely to be transported in LCM mobile toolkits. This case study also discussed how groups may have procured lithic toolstones, either through movement to outcrops, where they directly accessed raw materials, or via exchange relationships with LCM groups living in adjacent territories. The results from the production efficiency model are discussed in the context of each scenario. Overall, this case study shows that bladelet manufacture, which required highly efficient toolstones, influenced LCM mobility and toolkit management strategies. It is possible that LCM groups based their economies on large-scale residential movement or inter-group exchange networks. Either strategy (or perhaps a combination of both) would have helped groups adapt to environmental variation and risk by controlling how much foraging occurred within local patches by (a) moving through a habitual territory and expanding/contracting patch size, or (b) by moving to neighbors when environments were no longer productive.

2. Economic Patterns

The Initial Magdalenian case study presented in Chapter 2 addresses economic patterns through a comparison of Urtiaga cave with four other transitional assemblages in the Vasco-Cantabrian region. This comparison suggests that toolkit maintenance was a
key behavior that Initial Magdalenian groups followed to preserve lithic raw materials in their toolkits and to prolong tool use lives as they traversed the variable Last Glacial landscape. These results suggest human behavioral complexity beyond the artifact types that are routinely discussed as Initial Magdalenian temporal markers. They also propose that lithic assemblages formed through landscape-level patterns that may have adaptively varied to confront local circumstances. Furthermore, these results evidence patterned site and landscape use during the Initial Magdalenian that is further evidence of in situ development—local adaptive responses—of the Magdalenian archaeological culture from the preceding Solutrean as environments were shifting at the end of the Last Glacial Maximum.

Chapter 3 explores economic patterning through a detailed discussion of the lithic assemblage (and osseous industry) from El Mirón Level 504, including the debris and tool types manufactured and raw materials used. These analyses show that El Mirón occupations in the rear of the cave vestibule were focused on early stage flake and blade production coupled with late stage bladelet manufacture and that the assemblage is typical of the Lower Magdalenian in the Cantabrian region. LCM groups would have used this range of lithic products to carry out myriad tasks in order to adapt to local environmental circumstances present in the resource patches immediately surrounding the cave. Furthermore, the wealth of bladelet products corresponds to the elevated percentage of bladelet armatures (i.e., backed bladelets) in the Level 504 assemblage, and suggests that LCM groups may have been “gearing up” their mobile toolkits at a site that was located only a moderate distance from the high quality Barrika toolstone outcrop.
The case study presented in Chapter 4 summarizes lithic raw material use in the Vasco-Cantabrian region based on a sample of four sites in central Cantabria province. These stones indicate that LCM groups furnished their lithic toolkits with numerous raw materials and may have collected toolstones near their settlement locations and depleted these on-site in order to offset the cost of using conveyed toolstones. These analyses provide an economic baseline that archaeologists can use to interpret other aspects of LCM behavior (e.g., subsistence strategies). Finally, this case study shows that the Lower Magdalenian groups who occupied Cantabrian sites formed a regional band that can not only be defined by its unique art (see González Morales and Straus 2009), but by its economic (i.e., raw material provisioning) territory.

Finally, the fourth case study, Chapter 5, presents a mathematical model for lithic toolstone production efficiency and discusses how groups may have spatially organized themselves across the Vasco-Cantabrian landscape. The production efficiency model indicates that those lithic toolstones that LCM groups used to produce bladelets were the most efficient (highest quality) raw materials. The case study then compared production efficiency and raw material conveyance using the same samples analyzed in Chapter 4. These comparisons indicate that the most optimal LCM groups would have elected lithic raw materials with the greatest production efficiency in order to minimize procurement costs while maximizing the potential cutting edge they could manufacture from the toolstone.

3. Future Research

The case studies that have been included in this dissertation represent only a small portion of the published work that will result from the lithic analyses made as part of this
project. I plan to continue publishing my results in the coming years, including numerous summary articles for regional journals and major, problem-focused syntheses for international peer-reviewed journals. I also anticipate writing a book that is focused understanding development and change in the Magdalenian landscape in the Vasco-Cantabrian region, with particular attention to spatiotemporal variation in El Mirón cave. Pending further funding, I plan to expand my research related to how humans adapt to environmental complexity and change by sampling Vasco-Cantabrian sites that were occupied throughout the Upper Paleolithic in order to understand the influence(s) that climatic shifts had on human adaptations.

4. Contributions to Archaeology and Anthropology

This study provides an economic baseline that archaeologists investigating the Magdalenian period and/or the Vasco-Cantabrian region can use to interpret other aspects of these hunter-gatherers’ behavior (e.g., artistic activities, hunting strategies, etc.). In particular, this research has demonstrated that Vasco-Cantabrian Magdalenian groups organized their lithic economies on a landscape scale much larger than previous studies have indicated (e.g., Utrilla 1981). Additionally, that these groups organized their lithic toolkits on this large scale speaks to their ability to effectively navigate the Vasco-Cantabrian landscape and anticipate their stone tool needs as they responded to environmental complexity.

This project has utilized methods and frameworks that are uncommon in Paleolithic archaeology: lithic debris analysis (in addition to tools), landscape-level sampling, lithic technological organization, Human Behavioral Ecology, and mathematical modeling. These methodologies are highly replicable and should be of
interest to both Paleolithic prehistorians and archaeologists working in other world regions where lithic technological behaviors are of particular interest. There are two approaches described in the case studies that may be of particular interest to archaeologists worldwide. The first is the methodological procedure described in Chapter 2, which explains some ways that archaeologists can incorporate assemblages that were recovered using now outdated techniques into modern research frameworks. Incorporating these kinds of contexts into new research has the potential to increase anthropological understanding of prehistoric lifeways. The second methodology is the mathematical model for raw material production efficiency presented in Chapter 5. This model is an indirect method that archaeologists can use to quantify raw material quality, and may be especially useful to archaeologists who want to understand landscape-level lithic technological organization and toolkit management in regions with heterogeneous lithologies. Furthermore, because it is based on measurements that are standards in lithic analysis, it is highly replicable by other analysts.

This project contributes to anthropological understanding of the complexity in hunter-gatherer lifeways by exploring how these groups adapted to environmental variation in a mid-latitude coastal zone during an important period in human history: the Magdalenian. The Magdalenian was a “moment” in human history when people expanded their social networks, technologies, and ideas across a continent, on a grand scale in response to a climate that was ameliorating after the LGM crisis. The Magdalenian case can serve as a metaphor to our modern world, also ever-expanding and interconnected, and perhaps help us consider how we interact with our own environments in a (similarly) warming world.
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