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Local Raw Material Exploitation and Prehistoric Hunter-Gatherer Mobility

PAUL T. THACKER

Stone artifacts are the most common and longest-lasting elements of the archaeological record, a quality that helps explain the focus on lithic artifact analysis in Paleolithic and Paleoindian archaeology. Many of the earliest archaeological reconstructions of Late Pleistocene hunter-gatherer movement interpreted linear distance to exotic raw material sources as a direct indicator of mobility, initiating a set of assumptions that remain widely employed today. Yet the distance between the geological source and an artifact's recovery location is only a measure of the movement of a specific stone fragment. Such decontextualized raw material data rarely correlate with individual or group mobility, because numerous other processes influence raw material use and transport within hunter-gatherer lithic economies.

This chapter examines the interpretive significance of local raw material exploitation by incorporating insights from evolutionary ecology and resource use models within a diachronic regional approach. Constructing dynamic models of changing prehistoric hunter-gatherer mobility using contextualized flaked stone assemblages is theoretically possible, but the task is much more difficult than is commonly assumed. Middle-range arguments developed from diet-breadth ecological models imply that current hypotheses of mobility in Late Upper Paleolithic and Epipaleolithic Portuguese Estremadura warrant reassessment.

Transporting Artifacts, Individual Movement, and Residential Mobility: Scales and Significance

Obstacles to reconstructing prehistoric mobility stem from the very nature of the endeavor: understanding characteristics of a dynamic human settlement system by using the archaeological record, essentially a static residue. Ethnographic studies and ethnoarchaeology are critical and productive sources for pattern recognition and modeling of hunter-gatherer variability, including lithic organization and mobility strategies. Unfortunately, many archaeologists apply these models to the archaeological record without full consideration of their structural implications.

The well-used (and probably abused) forager-collector continuum described by Binford (1980) is an example of an anthropological model with complex inferences for discerning settlement strategies in archaeology. Residential movement is a critical concept for archaeological interpretation in the forager/collector framework. Foragers move camp more frequently and utilize a daily foraging radius, while collectors move base camps less frequently but rely on logistical forays to acquire resources located beyond the daily radius. Several studies of ethnographic groups have found relationships between number of annual moves, resource acquisition, and ranging behavior (Binford 2001; Kelly 1995).

As Kelly pointed out (1992), archaeologists are often vague in their definitions of mobility. The annual range traveled by a specific band is rarely correlated with the total territory exploited during an individual's lifetime. In many cases, individuals within the same band have significantly different foraging radii. A group may relocate its campsite many times during a year but not move very far, and vice versa. The number of residential moves per year is rarely directly related to annual range, except when other environmental relationships are considered (Binford 2001).

In addition to the manifold problem of frequency of residential movement versus overall range, archaeologists face a mire of equifinality upon realizing that in some cases certain raw materials in the form of *specific tools* may move farther when people move base camp less often. For example, specialized tools may be associated with tasks conducted during special-purpose, long-distance logistical forays. This behavioral association results in the transport of certain raw materials (used for these specialized tools) far from their geological sources even when residential mobility (base camp movement) is low. In contrast, lithic materials may move greater distances *in cobble or core form* in a system exhibiting increasing residential mobility (Binford 1979; Binford and O'Connell 1984).

Much confusion within archaeological middle-range theory concerning raw material exploitation originates in misconceptualizations of the archaeological record as a snapshot of ethnographic ranging behavior. Using Binford's caveat that organizational structure is the critical component for interpreting the structure of the archaeological record, archaeologists are wise to assume that sites do not represent events within an ethnographic range. Rather, the settlement and subsistence of a hunter-gatherer group had organizational consequences for raw material exploitation, site functions, and assemblage variability. The identification and explanation of structured patterning in the organization of a lithic technology can, in certain cases, anchor hypotheses of prehistoric hunter-gatherer systemic mobility (Gamble and Boismier 1991; Kuhn 1989). This undertaking is very different from attempting to document historical group movements (Close 1996, 2000).

In order to avoid these analytical pitfalls, archaeological evidence of raw material exploitation must be contextualized. Contextualization begins by evaluating lithic raw material exploitation practices within the geographical distribution of available lithic resources, including local and nonlocal materials. Against this characterized background, inter- and intra-assemblage variability and technological organization must supplement indicators of activities/site functions on a regional level. Contextualizing lithic exploitation and technological organization is a necessary prerequisite for incorporating lithic raw material data into systemic mobility reconstructions or interpretations.

Lithic Raw Materials as Ecological Resources

Within the interdisciplinary exchange between evolutionary ecology and anthropology, a number of studies have productively modeled human hunter-gatherers as resource managers (Williams and Hunn 1982; Smith and Winterhalder 1992). Rather than being real in any sense, such models are useful heuristically for developing possible explanations of archaeological patterning (Smith 1987) and identifying situations where human groups behave in notably counterintuitive ways.

Several concepts from evolutionary ecology have been adapted for use in lithic analysis, most visibly the attempts to discern the effects of time stress and buffering mechanisms on stone tool design and use-life (Torrence 1989; Edmonds 1987). The Paleoindian and Paleolithic archaeological community's emphasis (perhaps overemphasis) on indicators of risk management may be linked to the understandably seductive allure of concepts such as curation and design reliability. These concepts were not developed for analysis of stone tool technology. Thus valid critiques of them should not be surprising (Nash 1996; Odell 1996; Shott 1996); nor should the setbacks of such approaches indict the application of evolutionary ecological perspectives to hunter-gatherer prehistory. These archaeological applications have met with limited success precisely because of the problem of assemblage context. Isolated, single-site, or otherwise decontextualized lithic data are insufficient for robust modeling of prehistoric mobility strategies (Hill 1994; Odell 1994).

Patch-choice and diet-breadth models are two mainstays of food-resource exploitation models in anthropological evolutionary ecology (Bettinger 1991). These models are suitable foundations for building an ecological model of lithic resource exploitation, granted that appropriate modifications due to differences between organic food resources and inorganic lithic materials are necessary. Resource models in optimal foraging theory are geographical, describing behavior across a landscape of unevenly distributed resources of varying types

(Winterhalder 2001). Mapping lithic resource occurrences and characterizing distributions is a necessary first step for understanding prehistoric raw material exploitation practices (Church 1994).

Lithic resources are significantly different from organic counterparts on the landscape in those source areas:

(a) they are more predictably located;
(b) they are rarely exhausted and do not require rejuvenation;
(c) they are more predictable in terms of resource-return rates;
(d) they are not usually as time-dependent or time-variable (for example, seasonality).

Because of these crucial differences from biotic resources, patch-choice models have limited application for lithic studies. Diet-breadth models, however, hold more potential for understanding stone tool assemblage organization.

Several ethnographic food resource studies have demonstrated that the specific nature of an individual resource is an important determinant of strategies of exploitation and subsequent mobility decisions (Bettinger et al. 1997; Binford 2001). Specifically, diet-breadth models reconstruct possible food resources available for human consumption and compare these options with the resources actually exploited. The value in such an approach extends beyond confirming reasonable decisions by humans occupying a region; the approach frequently results in the discovery of counterintuitive relationships, such as the use of a lower-ranked resource when higher-ranked resources are plentiful (Bird 1997; Madsen and Schmitt 1998). Often human hunter-gatherers behave in a less than optimal manner, demonstrating the fundamentally social nature of information flow and the constructed elements of landscape and subsistence (Holt 1996; Mithen 1989, 1990).

Archaeological application of these ecological insights facilitates an explicitly geographic raw material selection model similar to those successfully applied to organic resources (Bonzani 1997; Grayson and Delpech 1998). Considering the diversity and availability of knappable raw materials is not new in archaeology (see Odell 1984; Reid 1997) and is an important consideration in the lithic sourcing literature (Church 1995; Shackley 1998).

This ecological analysis assumes that prehistoric groups knew the distribution of lithic resources when occupying or traversing a region. Such an assumption may not be warranted in all archaeological cases but is certainly reasonable in the vast majority of prehistoric situations (Torrence et al. 1996). Pioneering or migrating groups moving across an absolutely unknown territory were rare occurrences in prehistory; in those exceptional circumstances, most accepted evolutionary ecological resource models contain the same (if not more damaging) theoretical obstacles as this proposed raw material model (Clark 1994).

Generalizing handling costs is problematic for lithic resources as well as for food resources, and cost rankings and comparisons are necessarily left to the specific regional variability/technologies under investigation. In many cases, handling costs of stone may include quarrying/mining activities, differential decortification requirements, heat treatment, and the like. Fortunately most handling cost activities involving lithic materials generate recognizable signatures in the archaeological record, an advantage not shared by many organic resource procurement and processing activities.

The embedded nature of most lithic procurement observed ethnographically is a critical difference between lithic resource acquisition and many organic counterparts (Binford 1979). Rarely is stone the only or even the primary purpose of a hunter-gatherer's excursion (Gould and Saggers 1985; Haury 1994), so it is reasonable to consider the opportunity cost of procurement activities to be minimal relative to other foraging activities. That is, it is unnecessary to consider choosing to procure stone as calculated against obtaining food resources. Different stone sources (for example, an outcrop versus secondary occurrence in a gravel) or material types (fine quartzite versus quartz or chert), however, do have varying opportunity costs (Elston 1990). These differential costs, especially when both local and exotic stone are utilized in assemblages, underlie the archaeological interest in distance to raw material sources.

A prehistoric group's choice not to knap a locally available quartzite is of significance within this approach. As Kelly (1992: 55) argues, "To know what one resource offers means knowing what it offers relative to others." Ironically, this methodology, derived from evolutionary ecology, may discern elements of stone tool production and use that are *not* explainable except through a more complex theory of social action and/or reproduction (Clark 1999). In order to interpret the full relevance of raw material procurement choices, it is important to return again to context: namely, inter- and intra-assemblage variability in stone use.

Technological Organization and Raw Material Selection

The majority of lithic assemblages contain numerous raw material types, unevenly distributed across tool classes, reduction classes, core classes, and other categories. Rather than compressing variability into raw material trends within the assemblage as a whole, lithic analysis must focus attention on the distribution of raw materials across different assemblage classes and within varying reduction sequences (Hayden et al. 1996; Ingbar 1992). Often local raw materials were used for different purposes than exotic lithic resources (that is, locals may

constitute the majority of certain tool classes); or, more obviously, prehistoric knappers may have employed a different reduction strategy based on the type of raw material (Andrefsky 1998; Montet-White and Holen 1991). While separating assemblages into raw materials for analysis of technological organization is commonly done, middle-range theory to explain resulting patterns is poorly developed and rarely explicit. Several studies in both the Old and New Worlds have recognized the manufacture of expedient tools and utilized flakes on local raw materials (Bamforth 1990; Nelson 1991; Parry and Kelly 1987; Straus 1991a). The meaning of this assemblage pattern is clarified by examining the organization of nonlocal raw materials in the same assemblage.

Resource maximization and time minimization relationships have usefully characterized aspects of hunter-gatherer ecology (Bamforth and Bleed 1997; Winterhalder 2001). Torrence (1994) appropriately warns that knappers produce foremost a tool adequate for its purpose and only indirectly consider transport costs or conservation of raw materials. These functional constraints are occasionally evident within tool assemblage attributes and can be supported by experimental and use-wear studies.

After hypothesis formulation regarding functional use, analysis should incorporate models of resource maximization and time minimization in procurement and processing of stone raw material. For example, if a local quartz is suitable for making thick scrapers, and no other raw materials have lower opportunity costs, then thick scrapers should be made from local raw materials.

Mobility Mirages: Exotic Raw Materials and Specialized Tool Forms

The role of labor-intensive, highly formalized tools has dominated most middle-range articulation of the organization of technology with mobility strategies (Carr 1994; Goodyear 1989; Hofman 1991; Larick 1987). Often these discussions reach an impasse when acknowledging the possibilities of exchange and trade for exotic materials (Meltzer 1989). More significantly, these arguments can suffer from spuriousness when concluding that a formal tool type or technology is linked to increased mobility. For example, if Paleoindians preferred (for whatever reason, functional or aesthetic) to fashion lanceolate points on high-quality raw materials occurring at only a single source on the landscape, it is tautological to argue that Paleoindian technological organization reflects high mobility, using distance to sources as supporting evidence. Lithic analysis must include an assessment of the use of local raw materials for manufacturing informal tools and must document the relationship of high-quality and more likely exotic raw materials with the formalized tool elements (Holdaway et al. 1996;

Brantingham 2003). Research in this direction is most notably represented by several Northern European Mesolithic studies in the Old World (Myers 1989; Jochim 1998; Vierra 1995), Paleoindian research in North America (Amick 1999; Ellis and Deller 2000; Sellet 2004), and studies on later Prehistoric assemblages in New Mexico (Walsh 1998).

Assemblage Variability and Regional Context

A scatter of stone artifacts may represent the location of specific human activities associated with certain artifact classes, a discard area (transformation), the impact of geological postdepositional processes, or—even worse for the archaeologist—all of the above (Hayden 1998; Isaac 1986; Stern 1993). Lithic technological organization may vary within the same cultural system or even individual behavior, depending on geographical location, specific activity, and social setting (Hayden et al. 1996; Phillipson 1980). Refitting studies and indirect analogs (such as nodule-type methods) are promising methodologies for exploring variability in this realm (Almeida 2000; Larson and Kornfeld 1997; Roebroeks and Hennekens 1990; Sellet 1999). Nevertheless, a holistic and representative sample of lithic technological variability from a hunter-gatherer system is essential for any modeling of mobility (Henry 1989; Thacker 1996; Williams 2000). Numerous lithic studies have demonstrated that a regional approach is the best solution to this sampling and theoretical issue (Demars 1982; Dibble 1991; Ebert and Camilli 1993; Floss 1994; Thacker 2000).

Regional approaches are a critical source of data. Only through an integration of land use, site types, activity variation, and their effects on lithic organization may complex models of raw material exploitation be linked to settlement and subsistence and hence mobility strategies. A regional approach does not assume recovery of an articulated settlement system or ethnographically meaningful reconstruction of past ranges and territories. Regional analysis seeks organizational structure and strategies of systems, rather than historically real movements and boundaries. Multiple site assemblages strengthen hypotheses of lithic organizational significance and avoid the potential idiosyncrasy of interpretations based on one activity area or assemblage (Blankholm 1991; Eriksen 1991; Feblot-Augustins 1997). Diachronic approaches are useful for evaluating the theoretical assumptions of a model as systemic change occurs (Bernaldo de Quiros and Cabrera Valdes 1996; Montes Barquín and Sanguino-González 1998).

The Importance of Local Raw Material Exploitation for Reconstructing Hunter-Gatherer Mobility at the Pleistocene/Holocene Boundary: An Archaeological Application from Portugal

Seven assemblages from the Terminal Magdalenian and Epipaleolithic of Portugal illustrate the importance of on-site or near-site resources for understanding the interface between technological organization and settlement strategies. All seven assemblages are from open-air sites in the Rio Maior vicinity and six of them yielded charcoal for absolute dating (Table 11.1). These large assemblages were selected from more than a dozen Late Pleistocene/Early Holocene sites in the region due to functional interpretation: all seven sites are currently considered campsites (Bicho 2000, Marks et al. 1994; Marks and Mishoe 1997; Zilhão 1997a), based on the presence of stone-lined hearth features and site size. Regional Terminal Paleolithic land-use patterns appear identical to those of the Epipaleolithic, suggesting a continuity in overall site location strategy within the site sample (Thacker 1996b).

The paleoenvironment of the Rio Maior vicinity from 11,000 BP until about 8500 BP was rather temperate by European standards, with the exception of a mild cold period during the end of Dryas III, as Nuno Bicho (1994) documents. Vegetational communities at the end of the Pleistocene were a mix of Atlantic and Mediterranean species, with pine, oak, and birch species present in the region throughout the Terminal Paleolithic. Faunal communities contain rabbit, hare, red deer, roe deer, horse, aurochs, and wild boar, as well as some colder-adapted species such as goat (*Capra*) and chamois (*Rupicapra*) (Bicho et al. 2000; Hockett and Bicho 2000; Haws 2000). These two latter species disappeared by the Early Holocene, and oak gradually replaced pine in many areas. Most reconstructions depict the Early Holocene paleoenvironment of central Estremadura as essentially equivalent to modern conditions (Bicho 1993, 1994; Marks and Mishoe 1997; Zilhão 1997b).

Table 11.1. Radiocarbon Dates for the Late Upper Paleolithic and Epipaleolithic Assemblages of the Rio Maior Vicinity

Cabeço do Porto Marinho I-U	12,220 ±110
Cabeço do Porto Marinho III S-U	11,810 ±110
Carneira-Pinhal	10,880 ±90
Cabeço do Porto Marinho V	9,100 ±160
Areeiro III	8,860 ±80; 8,850±50; 8,570±130
Fonte Pinheiro	8,450 ±190

Faunal assemblages from archaeological sites during this period are rare and come mainly from caves exhibiting better preservation conditions. Limited comparative data on human diet across the Pleistocene/Holocene boundary preliminarily indicate no major changes except of degree, with probable parallels to the Cantabrian pattern of subsistence intensification through both specialization and diversification, culminating during the Mesolithic (Straus 1992, 1999; Bicho 1994).

The continuity between the Magdalenian and Final Epipaleolithic lithic technology has been demonstrated by several studies (Bicho 2000; Zilhão 1997a), with chronological change being limited to an apparent (but poorly documented) increasing frequency of geometrics produced using a microburin technique as the Holocene progressed. Limited and mostly conjectural settlement system reconstruction has focused on two observations: the apparent increase in the number of sites in Portugal during the Epipaleolithic and the proposal that inland-coastal movement "increased" and took on a more logistical organizational character due to the presence of marine resources in Estremaduran cave sites (Bicho 1994, 1997, 1998, 2000).

The Distribution of Lithic Raw Materials in the Rio Maior Vicinity

Using a lithic resource model requires detailing the occurrence of knappable raw materials in a region. There are two significant sources of lithic raw material in the Rio Maior vicinity, as discovered through a total coverage survey conducted from 1990 to 1993 (Thacker 2002). High-quality chert cobbles occur in secondary position, within gravels supporting the ridge separating the Rio Maior and Penegral drainage. These chert cobbles are exposed as intermittent and ephemeral perched streams incise the sands and gravels of the ridge during wet seasons. The second raw material source occurs as gravels of variable-quality quartz and quartzite that structurally support most of the landforms in the Rio Maior drainage. These gravel cobbles are exposed by stream and river erosion and occasionally by wind erosion/deflation of sand dunes or beds. More importantly, such gravels occur within a few minutes' walk of all the sites included in this chapter and, in fact, of any point in the drainage except on the limestone uplands. In addition to quartz and quartzites, these gravels contain small and variable frequencies of sandstones, siltstones, basalt, limestone, and rock crystal. Thus human groups in the valley during the Late Pleistocene and Early Holocene were selecting raw materials either from an essentially on- or near-site context or from the chert deposits, still well within a daily foraging radius.

Detecting the Shift to a Specialized, Diversified Subsistence/Settlement Strategy Using Stone Tool Assemblages

Current hypotheses concerning change in subsistence and settlement in Portuguese Estremadura during the Epipaleolithic propose the following:

(1) The increased use of specialized tool kits, especially geometrics, throughout the Epipaleolithic, culminating in the Mesolithic (Bicho 1998, 2000).
(2) An increasing logistical strategy of mobility, evidenced by faunal assemblages from inland Epipaleolithic cave sites (Straus 1992; Straus et al. 2000; Vierra 1995; Bicho 1994).
(3) An expedient use of local raw materials. Bicho (1997, 1998) proposed that, rather than being embedded in other activities, the "necessity" of chert procurement for manufacturing bladelet and geometric barbs impacted settlement systems, resulting in site location (albeit logistical camps) near known chert sources.

Diachronic tool type richness-diversity measures are a productive way to control for sample sizes and assess assemblage variability in tool form (Jones et al. 1989; Simek and Price 1990). Published tool typologies from the six sites are directly comparable and have minimal bias originating in methodological or investigator effects. All but one were analyzed by A. E. Marks and Bicho; Fonte Pinheiro was analyzed by Thacker and Bicho. The specific types included in the lists are based on the Upper Paleolithic typological scheme of Denise de Sonneville-Bordes, adapted for Portugal by Marks and João Zilhão (Marks et al. 1994; Zilhão 1997a). No retouched tool types are chronologically sensitive across the time range spanned by the assemblages (a necessary prerequisite for such diversity measures). The entire type list was chosen for the richness scale, because compressing individual types into tool classes does not, in this case, alter results.

As reported in Table 11.2, tool diversity at each site is predominantly a function of sample size. While the difference is not statistically significant, assemblages from the later periods contain slightly fewer tool types than the Terminal Magdalenian ones. Likewise, the percentage of geometrics and microburins in the tool assemblage shows no significant variability until Fonte Pinheiro, which is dated to the Final Epipaleolithic/Earliest Mesolithic (8450 years BP). In sum, using these assemblages from seemingly similar functional contexts (campsites), it is difficult to argue for major or even minor directional change in formal tool-kit design during the Terminal Pleistocene and Epipaleolithic. The only change in tool-kit diversity occurs at the Epipaleolithic/ Mesolithic transition.

Table 11.2. Lithic Tool Assemblage Diversity

Site	Number of tools	Number of tool types	% of geometrics
Cabeço do Porto Marinho I-U	1,481	72	0.4
Cabecço do Porto Marinho III S-U	372	55	1.3
Carneira-Pinhal	200	42	0
Cabeço do Porto Marinho V	157	39	3.1
Carneira II	171	42	8.2
Areeiro III	554	45	0.2
Fonte Pinheiro	211	40	15.4

If Epipaleolithic hunter-gatherers were increasingly logistically organized, what structural changes should occur within large campsite lithic assemblages? Base camps or residential campsites are occupied for longer durations in logistical strategies, as the movement focus involves bringing "resources to people" (Kuhn 1992, 1995). Lithic assemblages from campsites occupied for longer durations will more likely contain several organizational strategies across different functional activities and possibly across raw material categories, which may be discernible through activity area differentiation (Torrence 2001). Conversely, the archaeological patterns produced by a highly specialized, logistical subsistence and settlement system will rarely exhibit extremely flexible, minimally differentiated reduction and use of tools. Unfortunately, site maintenance activities, such as surface sweeping and secondary discard activities, are also more likely to occur at longer-occupied locations. As emphasized above, equivalent functional context is critical for building these hypotheses using lithic assemblages.

Table 11.2 displays the frequencies of tools and cores in each Portuguese assemblage. The greatest variability between assemblages occurs during the Late Upper Paleolithic (CPM I-U and CPM III-S) and again at the Epipaleolithic/Mesolithic boundary. No significant change occurs through the Epipaleolithic in the frequency of tools or cores in the campsite assemblages. This observation corroborates earlier doubts as to a major transformation or trend in the organization of technology between the Late Upper Paleolithic and Epipaleolithic. While the percentage of on-site/near-site quartz and quartzite cores does not vary with time, the use of such local raw materials for tools does slightly increase at the Epipaleolithic/Mesolithic transition.

Table 11.3 demonstrates that in the Portuguese case, over 96% of informal tools throughout the Epipaleolithic were produced on chert rather than on quartz or quartzite. Again, a noticeable shift to more informal tools on local raw materials occurs at the Epipaleolithic/Mesolithic transition. Within the

Table 11.3. Informal Tool Production on On-Site or Near-Site Raw Materials

Site	% of informal tools on quartz and quartzite	% of quartz and quartzite tools that are informal
Cabeço do Porto Marinho I-U	0.03	0.33
Cabeço do Porto Marinho III S-U	0.04	0.36
Carneira-Pinhal	0.02	0.33
Cabeço do Porto Marinho V	0	0
Carneira II	0.02	0.50
Areeiro III	0.03	0.40
Fonte Pinheiro	0.29	0.50

quartz and quartzite tool assemblages from all periods, tools on local raw materials were more likely to be informal after about 9000 BP. This limited use of local materials for informal tools coupled with the lack of change in broader technological organization makes it unlikely that these Portuguese assemblages demonstrate a shift to longer-duration base camp settlement before about 9000 BP, and possibly not until around 8500 BP.

In conclusion, context-focused artifact analysis revises interpretation of lithic assemblages from Epipaleolithic Portugal. In central Estremadura there is no evidence for a significant change in technological organization or raw material exploitation until the end of the Epipaleolithic. If settlement strategies changed during the Epipaleolithic, they did so without fundamentally altering the technology or organization of lithic assemblages. Residential mobility between the coastal areas and inland Portugal, rather than logistical strategies, may explain the presence of coastal marine resources near Rio Maior. Transporting a previously unexploited (or untransported) food resource during a residential move, while a change in subsistence strategy, does not necessarily require a change in mobility. Lithic organizational patterns from the Rio Maior region are consistent with the hypothesis that the number of residential moves per year and distance traveled may not have changed significantly between the Late Upper Paleolithic and the Epipaleolithic.

Conclusions

Stone artifacts may reflect broad hunter-gatherer organizational attributes, such as mobility; but numerous other processes influence raw material use within lithic economies. Documenting the transport of an artifact differs fundamentally from identifying group movement or understanding the structural organization of mobility. Any middle-range theory linking the archaeological record of stone artifact assemblages to the dynamics of settlement system structure must emphasize the context of raw material exploitation within a technology. Prehistoric lithic economies can be contextualized by combining an ecological model of raw material availability with a regional approach integrating assemblage data across raw materials. As the Portuguese Epipaleolithic case study illustrates, focusing on the role of local raw materials and informal tool manufacturing *lessens* the risk of modeling spurious relationships between technological organization and hunter-gatherer mobility.

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References

Almeida, F.
2000 The Terminal Gravettian of Portuguese Estremadura: Ecological Variability of the Lithic Industries. Ph.D. dissertation. Southern Methodist University, Dallas.
Amick, D. S.
1999 Raw Material Variation in Folsom Stone Tool Assemblages and the Division of Labor in Hunter-Gatherer Societies. In *Folsom Lithic Technology: Explorations in Structure and Variation,* edited by D. Amick, pp. 169–187. Archaeological Series No. 12. International Monographs in Prehistory, Ann Arbor.
Andrefsky, W.
1994 Raw Material Availability and the Organization of Technology. *American Antiquity* 59: 21–35.
1998 *Lithics: Macroscopic Approaches to Analysis.* Cambridge University Press, Cambridge.
Bamforth, D. B.
1990 Settlement, Raw Material, and Lithic Procurement in the Central Mohave Desert. *Journal of Anthropological Archaeology* 9: 70–104.
Bamforth, D. B., and P. Bleed
1997 Technology, Flaked Stone Technology, and Risk. In *Rediscovering Darwin: Evolutionary Theory and Archeological Explanation*, edited by C. M. Barton and G. A. Clark, pp. 109–140. Archaeological Papers. American Anthropological Association, Washington, D.C.
Bernaldo de Quiros, F., and V. Cabrera Valdés
1996 Raw Material in the Paleolithic of Cueva del Castillo and in the Cantabrian Region. In *Non-Flint Stone Tools and the Palaeolithic Occupation of the Iberian Peninsula*, edited by N. Moloney et al., pp. 21–32. BAR, Oxford.
Bettinger, R. L.
1991 *Hunter-Gatherers: Archaeological and Evolutionary Theory.* Plenum Press, New York.
Bettinger, R. L., R. Malhi, and H. McCarthy
1997 Central Place Models of Acorn and Mussel Processing. *Journal of Archaeological Science* 24: 887–899.
Bicho, N.
1993 Late Glacial Prehistory of Central and Southern Portugal. *Antiquity* 67: 761–775.
1994 The End of the Paleolithic and the Mesolithic of Portugal. *Current Anthropology* 35: 664–673.
1997 Spatial, Technological, and Economic Organization after the Last Glacial Maximum in Portuguese Prehistory. In *El Món Mediterrani després del Pleniglacial (18,000–12,000 B.P.)*, edited by J. M. Fullola and N. Soler, pp. 213–223. Museu d'Árqueologia de Catalunya, Girona.
1998 The Pleistocene-Holocene Transition in Portuguese Prehistory: A Technological Perspective. In *The Organization of Lithic Technology in Late Glacial and Early Postglacial Europe*, edited by S. Milliken, pp. 39–62. BAR, Oxford.
2000 *Technological Change in the Final Upper Paleolithic of Rio Maior.* Arkeos, Tomar.
Bicho, N., B. Hockett, J. Haws, and W. Belcher
2000 Hunter-Gatherer Subsistence at the End of the Pleistocene: Preliminary Results from Picareiro Cave, Central Portugal. *Antiquity* 74: 500–506.
Binford, L. R.
1979 Organization and Formation Processes: Looking at Curated Technologies. *Journal of Anthropological Research* 35: 255–273.
1980 Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45: 4–20.
2001 *Constructing Frames of Reference.* University of California Press, Berkeley.
Binford, L. R., and J. F. O'Connell
1984 An Alyawara Day: The Stone Quarry. *Journal of Anthropological Research* 40: 406–432.
Bird, D. W.
1997 Behavioral Ecology and the Archaeological Consequences of Central Place Foraging among the Meriam. In *Rediscovering Darwin: Evolutionary Theory and Archeological Explanation*, edited by C. M. Barton and G. A. Clark, pp. 291–306. Archaeological Papers. American Anthropological Association, Washington, D.C.
Blankholm, H. P.
1991 *Intrasite Spatial Analysis in Theory and Practice.* Aarhus University Press, Aarhus.

Bonzani, R. M.
1997 Plant Diversity in the Archaeological Record: A Means toward Defining Hunter-Gatherer Mobility Strategies. *Journal of Archaeological Science* 24: 1129–1139.
Brantingham, P. J.
2003 A Neutral Model of Stone Raw Material Procurement. *American Antiquity* 68(3): 487–509.
Carr, P. J.
1994 Technological Organization and Prehistoric Hunter-Gatherer Mobility: Examination of the Hayes Site. In *The Organization of North American Prehistoric Chipped Stone Tool Technologies*, edited by P. J. Carr, pp. 35–44. Archaeological Series No. 7. International Monographs in Prehistory, Ann Arbor.
Church, T.
1994 *Lithic Resource Studies: A Sourcebook for Archaeologists*. Lithic Technology Special Publication 3. Department of Anthropology, University of Tulsa, Tulsa.
1995 Comment on "Neutron Activation Analysis of Stone from the Chadron Formation and a Clovis Site on the Great Plains" by Hoard et al. (1992). *Journal of Archaeological Science* 22: 1–5.
Clark, G. A.
1994 Migration as an Explanatory Concept in Paleolithic Archaeology. *Journal of Archaeological Method and Theory* 1: 305–343.
Clark, J. E.
1999 Comments on "Stone Tools." *Lithic Technology* 24: 126–135.
Close, A.
1996 Carry That Weight: The Use and Transportation of Stone Tools. *Current Anthropology* 37: 545–553.
2000 Reconstructing Movement in Prehistory. *Journal of Archaeological Method and Theory* 7: 49–78.
Demars, P.
1982 *L'utilisation du silex au Paléolithique Supérieur: Choix, approvisionnement, circulation—L'Exemple du bassin de Brive*. CNRS, Paris.
Dibble, H.
1991 Mousterian Assemblage Variability on an Interregional Scale. *Journal of Anthropological Research* 47: 239–258.
Ebert, J., and E. Camilli
1993 Lithic Distributions and Their Analytical Potential: An Example. *Lithic Technology* 18: 95–105.
Edmonds, M.
1987 Rocks and Risk: Problems with Lithic Procurement Strategies. In *Lithic Analysis and Later British Prehistory*, edited by A. G. Brown and M. R. Edmonds, pp. 155–180. BAR, Oxford.

Ellis, C., and D. B. Deller
2000 *An Early Paleo-Indian Site near Parkhill, Ontario*. Canadian Museum of Civilization, Quebec.
Elston, R. G.
1990 A Cost-Benefit Model of Lithic Assemblage Variability. In *The Archaeology of James Creek Shelter*, edited by R. G. Elston and E. E. Budy, pp. 153–163. Anthropological Paper 115. University of Utah Press, Salt Lake City.
Eriksen, B. V.
1991 *Change and Continuity in a Prehistoric Hunter-Gatherer Society*. Archaeologica Venatoria, Tübingen.
Feblot-Augustins, J.
1997 *La circulation des matières premières au Paléolithique*. 2 vols. ERAUL, Liège.
Floss, H.
1994 *Rohmaterialversorgung im Paläolithikum des Mittelrheingebietes*. RGZM Monographs No. 21. Habelt, Bonn.
Gamble, C. S., and W. A. Boismier
1991 *Ethnoarchaeological Approaches to Mobile Campsites*. International Monographs in Prehistory, Ann Arbor.
Goodyear, A. C.
1989 A Hypothesis for the Use of Cryptocrystalline Raw Materials among Paleoindian Groups of North America. In *Eastern Paleoindian Lithic Resource Use*, edited by C. Ellis and J. Lothrop, pp. 1–9. Westview Press, Boulder.
Gould, R. A., and S. Saggers
1985 Lithic Procurement in Central Australia: A Closer Look at Binford's Idea of Embeddedness in Archaeology. *American Antiquity* 50: 117–136.
Grayson, D. K., and F. Delpech
1998 Changing Diet-Breadth in the Early Upper Paleolithic of Southwestern France. *Journal of Archaeological Science* 25: 1119–1129.
Haury, C. E.
1994 Defining Lithic Procurement Terminology. In *Lithic Resource Studies: A Sourcebook for Archaeologists*, edited by T. Church, pp. 26–31. Lithic Technology Special Publication 3. Department of Anthropology, University of Tulsa, Tulsa.
Haws, J.
2000 Tardiglacial Subsistence and Settlement in Central Portugal. In *Paleolítico da Península Ibérica: Actas do 3 Congresso de Arqueologia Peninsular*, vol. 2, edited by V. O. Jorge, pp. 403–413. ADECAP, Porto.
Hayden, B.
1998 Practical and Prestige Technologies: The Evolution of Material Systems. *Journal of Archaeological Method and Theory* 5: 1–59.
Hayden, B., E. Bakewell, and R. Gargett
1996 The World's Longest Lived Corporate Group: Lithic Analysis Reveals Prehistoric

Social Organization near Lillooet, British Columbia. *American Antiquity* 61: 341–356.

Hayden, B., N. Franco, and J. Spafford
1996 Evaluating Lithic Strategies and Design Criteria. In *Stone Tools: Theoretical Insights into Human Prehistory*, edited by G. Odell, pp. 9–47. Plenum Press, New York.

Henry, D.
1989 Correlations between Reduction Strategies and Settlement Patterns. In *Alternative Approaches to Lithic Analysis*, edited by D. Henry and G. Odell, pp. 139–156. Archaeological Papers. American Anthropological Association, Washington, D.C.

Hill, A.
1994 Early Hominid Behavioural Ecology: A Personal Postscript. *Journal of Human Evolution* 27: 321–328.

Hockett, B. S., and N. Bicho
2000 Small Mammal Hunting during the LUP of Central Portugal. In *Paleolítico da Península Ibérica: Actas do 3 Congresso de Arqueologia Peninsular*, vol. 2, edited by V. O. Jorge, pp. 415–424. ADECAP, Porto.

Hofman, J. L.
1991 Folsom Land Use: Projectile Point Variability as a Key to Mobility. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 335–356. Publications in Anthropology 19. University of Kansas, Lawrence.

Holdaway, S., S. McPherron, and B. Roth
1996 Notched Tool Reuse and Raw Material Availability in French Middle Paleolithic Sites. *American Antiquity* 61(2): 377–387.

Holt, J. Z.
1996 Beyond Optimization: Alternative Ways of Examining Animal Exploitation. *World Archaeology* 28: 89–109.

Ingbar, E. E.
1992 The Hanson Site and Folsom on the Northwestern Plains. In *Ice Age Hunters of the Rockies*, edited by D. Stanford and J. Day, pp. 169–192. Denver Museum of Natural History, Denver.
1994 Lithic Material Selection and Technological Organization. In *The Organization of North American Prehistoric Chipped Stone Tool Technologies*, edited by P. J. Carr, pp. 45–56. Archaeological Series No. 7. International Monographs in Prehistory, Ann Arbor.

Isaac, G. L.
1986 Foundation Stones: Early Artefacts as Indicators of Activities and Abilities. In *Stone Age Prehistory: Studies in Memory of Charles McBurney*, edited by G. N. Bailey and P. Callow, pp. 221–241. Cambridge University Press, Cambridge.

Jochim, M. A.
1989 Optimization and Stone Tool Studies: Problems and Potential. In *Time, Energy, and Stone Tools*, edited by R. Torrence, pp. 106–111. Cambridge University Press, Cambridge.
1990 The Ecosystem Concept in Archaeology. In *The Ecosystem Approach in Anthropology: From Concept to Practice*, edited by E. F. Moran, pp. 75–90. University of Michigan Press, Ann Arbor.
1998 *A Hunter-Gatherer Landscape: Southwest Germany in the Late Paleolithic and Mesolithic*. Plenum Press, New York.

Jones, G. T., C. Beck, and D. K. Grayson
1989 Measures of Diversity and Expedient Lithic Technology. In *Quantifying Diversity in Archaeology*, edited by R. Leonard and G. T. Jones, pp. 69–78. Cambridge University Press, Cambridge.

Kelly, R.
1992 Mobility/Sedentism: Concepts, Archaeological Measures, and Effects. *Annual Review of Anthropology* 21: 43–66.
1994 Some Thoughts on Future Directions in the Study of Stone Tool Technological Organization. In *The Organization of North American Prehistoric Chipped Stone Tool Technologies*, edited by P. J. Carr, pp. 132–136. Archaeological Series No. 7. International Monographs in Prehistory, Ann Arbor.
1995 *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Smithsonian Institution Press, Washington, D.C.

Kuhn, S.
1989 Hunter-Gatherer Foraging Organization and Strategies of Artifact Replacement and Discard. In *Experiments in Lithic Technology*, edited by D. Amick and R. Mauldin, pp. 33–45. BAR, Oxford.
1992 On Planning and Curated Technologies in the Middle Paleolithic. *Journal of Anthropological Research* 48: 185–214.
1994 A Formal Approach to the Design and Assembly of Transported Toolkits. *American Antiquity* 59: 426–442.
1995 *Mousterian Lithic Technology: An Ecological Perspective*. Princeton, Princeton University Press.

Larick, R.
1987 Perigord Cherts: An Analytical Frame for Investigating the Movement of Paleolithic Hunter-Gatherers and Their Resources. In *The Scientific Study of Flint and Chert*, edited by G. Sieveking and M. Hart, pp. 111–120. Cambridge University Press, Cambridge.

Larson, M. L., and M. Kornfeld
1997 Chipped Stone Nodules: Theory, Method, and Examples. *Lithic Technology* 22: 4–18.

Madsen, D., and D. Schmitt
1998 Mass Collecting and the Diet-Breadth Model: A Great Basin Example. *Journal of Archaeological Science* 25: 445–455.
Marks, A. E., N. Bicho, J. Zilhão, and C. R. Ferring
1994 Upper Pleistocene Prehistory in Portuguese Estremadura: Results of Preliminary Research. *Journal of Field Archaeology* 21: 53–68.
Marks, A. E., and M.-B. Mishoe
1997 The Magdalenian of Portuguese Estremadura. In *El Món Mediterrani després del Pleniglacial (18,000–12,000 B.P.)*, edited by J. M. Fullola and N. Soler, pp. 225–232. Museu d'Árqueologia de Catalunya, Girona.
Meltzer, D.
1989 Was Stone Exchanged among Eastern North American Paleoindians? In *Eastern Paleo-Indian Lithic Resource Use*, edited by C. Ellis and J. Lothrop, pp. 11–39. Westview Press, Boulder.
Mithen, S. J.
1989 Modeling Hunter-Gatherer Decision Making: Complementing Optimal Foraging Theory. *Human Ecology* 17: 59–83.
1990 *Thoughtful Foragers: A Study in Prehistoric Decision Making.* Cambridge University Press, Cambridge.
Montes Barquín, R., and J. Sanguino-González
1998 Diferencias en las estrategias de adquisición de recursos líticos entre el Paleolítico Inferior y Medio en el centro de la Región Cantábrica: Implicaciones económicas y territoriales. In *Los recursos abióticos en la prehistoria*, edited by J. Bernabeu et al., pp. 55–71. Universitat de València, Valencia.
Montet-White, A., and S. Holen
1991 *Raw Material Economies among Prehistoric Hunter-Gatherers.* Publications in Anthropology 19. University of Kansas, Lawrence.
Myers, A.
1989 Reliable and Maintainable Technological Strategies in the Mesolithic of Mainland Britain. In *Time, Energy, and Stone Tools*, edited by R. Torrence, pp. 78–90. Cambridge University Press, Cambridge.
Nash, S.
1996 Is Curation a Useful Heuristic? In *Stone Tools: Theoretical Insights into Human Prehistory*, edited by G. Odell, pp. 81–99. Plenum Press, New York.
Nelson, M. C.
1991 The Study of Technological Organization. *Archaeological Method and Theory* 3: 57–100.
Odell, G.
1984 Chert Resource Availability in the Lower Illinois Valley: A Transect Sample. In *Prehistoric Chert Exploitation: Studies from the Midcontinent*, edited by B. Butler and E. May, pp. 45–67. Center for Archaeological Investigations Occasional Papers 2. Southern Illinois University, Carbondale.

1994 Assessing Hunter-Gatherer Mobility in the Illinois Valley: Exploring Ambiguous Results. In *The Organization of North American Prehistoric Chipped Stone Tool Technologies*, edited by P. J. Carr, pp. 70–86. Archaeological Series No. 7. International Monographs in Prehistory, Ann Arbor.
1996 Economizing Behavior and the Concept of Curation. In *Stone Tools: Theoretical Insights into Human Prehistory*, edited by G. Odell, pp. 51–79. Plenum Press, New York.
2000 Stone Tool Research at the End of the Millennium: Procurement and Technology. *Journal of Archaeological Research* 8(4): 269–331.
Parry, W. J., and R. L. Kelly
1987 Expedient Core Technology and Sedentism. In *The Organization of Core Technology*, edited by J. Johnson and C. Morrow, pp. 285–304. Westview Press, Boulder.
Phillipson, D. W.
1980 Technological Disparity or the Contemporaneity of Diverse Industries. In *Proceedings of the 8th Panafrican Congress of Prehistory and Quaternary Studies*, edited by R. Leakey et al., pp. 15–16. ILLMIAP, Nairobi.
Reid, K. C.
1997 Gravels and Travels: A Comment on Andrefsky's "Cascade Phase Lithic Technology." *North American Archaeologist* 18(1): 67–81.
Roebroeks, W., and P. Hennekens
1990 Transport of Lithics in the Middle Paleolithic: Conjoining Evidence from Maastricht-Belvedere (NL). In *The Big Puzzle*, edited by E. Cziesla et al., pp. 283–295. Holos, Bonn.
Sellet, F.
1999 A Dynamic View of Paleoindian Assemblages at the Hell Gap Site, Wyoming: Reconstructing Lithic Technological Systems. Ph.D. dissertation. Department of Anthropology, Southern Methodist University. University Microfilms, Ann Arbor.
2004 Beyond the Point: Projectile Manufacture and Behavioral Influence. *Journal of Archaeological Science* 31: 1553–1566.
Shackley, M. S.
1998 Gamma Rays, X-Rays, and Stone Tools: Some Recent Advances in Archaeological Geochemistry. *Journal of Archaeological Science* 25: 259–270.
Shott, M. J.
1996 An Exegesis of the Curation Concept. *Journal of Anthropological Research* 52(3): 259–280.
Simek, J., and H. Price
1990 Chronological Change in Perigord Lithic Assemblage Diversity. In *The Emergence of Modern Humans*, edited by P. Mellars, pp. 243–261. Cornell University Press, Ithaca.

Smith, E. A.
1987 Optimization Theory in Anthropology: Application and Critiques. In *The Latest on the Best: Essays on Evolution and Optimality*, edited by J. Dupre, pp. 201–249. Cambridge University Press, Cambridge.
Smith, E. A., and B. Winterhalder (editors)
1992 *Evolutionary Ecology and Human Behavior*. Aldine de Gruyter, New York.
Stern, N.
1993 The Structure of the Lower Pleistocene Archaeological Record—A Case Study from the Koobi Fora Formation. *Current Anthropology* 34(3): 201–226.
Straus, L. G.
1991a The Role of Raw Materials in Upper Paleolithic and Mesolithic Stone Artifact Assemblage Variability in Southwest Europe. In *Raw Material Economies among Prehistoric Hunter-Gatherers*, edited by A. Montet-White and S. Holen, pp. 169–186. Publications in Anthropology 19. University of Kansas, Lawrence.
1991b Southwestern Europe at the Last Glacial Maximum. *Current Anthropology* 32: 189–199.
1992 *Iberia before the Iberians*. University of New Mexico Press, Albuquerque.
1999 High Resolution Archeofaunal Records across the Pleistocene Holocene Transition on a Transect between 43 and 51 Degrees North Latitude in Western Europe. In *Zooarchaeology of the Pleistocene/Holocene Boundary*, edited by J. Driver, pp. 21–29. BAR, Oxford.
Straus, L., N. Bicho, and A. Winegardner
2000 Mapping the Upper Paleolithic regions of Iberia. *Journal of Iberian Archaeology* 2: 7–42.
Thacker, P.
1996a Hunter-Gatherer Lithic Economy and Settlement Systems: Understanding Regional Assemblage Variability in the Upper Paleolithic of Portuguese Estremadura. In *Stone Tools: Theoretical Insights into Human Prehistory*, edited by G. Odell, pp. 101–126. Plenum Press, New York.
1996b A Landscape Perspective on Upper Paleolithic Settlement in Portuguese Estremadura. Ph.D. dissertation. Southern Methodist University, Dallas.
2000 The Relevance of Regional Analysis for Upper Paleolithic Archaeology: A Case Study from Portugal. In *Regional Approaches to Adaptation in Late Pleistocene Western Europe*, edited by G. Peterkin and H. Price, pp. 25–45. BAR. Archeopress, Oxford.
2002 Residential Mobility and Lithic Economizing Behavior: Explaining Technological Change in the Portuguese Upper Paleolithic. In *Lithic Raw Material Economies in Late Glacial and Early Postglacial Europe*, edited by L. Fisher and B. Eriksen, pp. 147–159. BAR. Archeopress, Oxford.
Torrence, R.
1989 *Time, Energy, and Stone Tools*. Cambridge University Press, Cambridge.
1994 Strategies for Moving On in Lithic Studies. In *The Organization of North American Prehistoric Chipped Stone Tool Technologies*, edited by P. J. Carr, pp. 123–131. Archaeological Series No. 7. International Monographs in Prehistory, Ann Arbor.
2001 Hunter-Gatherer Technology: Macro- and Micro-Scale Approaches. In *Hunter-Gatherers: An Interdisciplinary Perspective*, edited by C. Panter-Brick, R. Layton, and P. Rowley-Conwy, pp. 73–98. Cambridge University Press, Cambridge.
Torrence, R., J. Specht, R. Fullagar, and G. R. Summerhayes
1996 Which Obsidian Is Worth It?: A View from the West New Britain Sources. In *Oceanic Culture History*, edited by J. M. Davidson et al., pp. 211–224. Special Publication of the *New Zealand Journal of Archaeology*.
Vierra, B. J.
1995 *Subsistence and Stone Tool Technology: An Old World Perspective*. Anthropological Papers 47. Arizona State University, Tempe.
Walsh, M. R.
1998 Lines in the Sand: Competition and Stone Selection on the Pajarito Plateau, New Mexico. *American Antiquity* 63: 573–593.
Williams, J. K.
2000 Land Use and Technological Trends in the Levantine Upper Paleolithic. *Journal of the Israel Prehistoric Society* 30: 33–47.
Williams, N. M., and E. S. Hunn (editors)
1982 *Resource Managers: North American and Australian Hunter-Gatherers*. AAAS Selected Symposium 67. Westview Press, Boulder.
Winterhalder, B.
2001 The Behavioral Ecology of Hunter-Gatherers. In *Hunter-Gatherers: An Interdisciplinary Perspective*, edited by C. Panter-Brick, R. Layton, and P. Rowley-Conwy, pp. 12–38. Cambridge University Press, Cambridge.
Zilhão, J.
1997a *O Paleolítico Superior da Estremadura Portuguesa*. Edições Colibri, Lisbon.
1997b The Paleolithic Settlement of Portuguese Estremadura after the Last Glacial Maximum. In *El Món Mediterrani després del Pleniglacial (18,000–12,000 B.P.)*, edited by J. M. Fullola and N. Soler, pp. 233–242. Museu d'Àrqueologia de Catalunya, Girona.