CHAPTER 2
PRESENTATION OF A MODEL FOR LITHIC ECONOMY

COMPONENTS OF THE MODEL

The focus of the model presented here is on the relationship between lithic raw materials and lithic economy: how raw material context affects strategies for procurement, reduction, and utilization. The distinction between a generalized and a specialized economy is defined by the presence or absence of differential procurement, reduction, and utilization strategies. Therefore, the factors affecting such differentiation are related to variability in different aspects of raw material.

The main factors are identified as quality and abundance (including distance to sources and distribution). *Quality* is defined in relation to specific techniques of manufacture and is measured first by the ability of a material to produce the intended blanks and then by the productivity, or maximum potential, of blanks that can be produced. Blank-production can be size dependent: if there is a minimum size requirement or preference, then small nodules and cobbles are of relatively "poorer" quality. Three general techniques are defined based on the types of blanks produced: production of simple flakes, predetermined Levallois flakes, blades and points, and prismatic blades/bladelets. Ordinary flakes require a minimum of core preparation: cortex removal (optional) and the preparation of a striking surface. The Levallois method is defined on the basis of its elaborate processes of core preparation which permit the removal of blanks of predetermined shape. Here, after a removal or short series of removals, the core must again be prepared. Core preparation for prismatic blade technology occurs in the first stages but once the platform is prepared, a continuous series of blades can be produced, with trimming of the platform lip and ridges when necessary. For each technique, materials can be ranked by maximum potential in terms of number of useable blanks that can be produced. Maximum potential is thus a correlate or index of quality. It is independent of perceived needs and provides a means of ranking materials by quality.

Availability is defined in terms of distances from source(s) to a given site and is necessarily dependent on site location. The distribution of lithic resources across the landscape can be patchy or uneven (as is the case in Belgium) versus consistent or evenly distributed. As the distance between source and site increases, the material in question is defined as less available, with a corresponding increase in time and energy expenditure for procurement as a function of distance.

The interaction between raw material and techniques of manufacture is identified by strategies for procurement and reduction and there are costs associated with these strategies. *Procurement costs* are defined as time spent traveling to and from the source, plus handling (carrying) costs which would be measured in energy units. Because it is not possible to calculate actual time and energy costs (e.g., in calories, as is done in foraging models), the distance from source to site is the best available estimate for procurement costs. Absolute distances, taking into account local topography, provide a relative estimate of procurement costs between different sources to one site. Using proportional information from assemblage-specific data, distance can be multiplied by proportion within an assemblage to calculate procurement cost for different materials. Procurement cost for local materials can also be estimated and an overall assemblage procurement cost can be calculated by summing the individual costs.

Labor costs incurred during the process of reduction are defined as the amount of time and energy spent during blank-production sessions and as decreasing productivity of cores as they become smaller. The first includes decreased ability to reduce smaller cores and decreasing ability to prepare the core, where the assumption is that it becomes more difficult technically or more time-consuming to reduce very small cores to produce suitable blanks. The second includes decrease in the size of blanks produced, perhaps relevant to size needs for tools, and decrease in the number of blanks that can be produced from very small cores.

During the process of procurement and transport, costs or expenses are time and energy. Once material has arrived at the site, expenses are a function of quality. As relative quality of material decreases (e.g., if good quality material is unavailable and poorer quality materials must be used), expenses increase. These expenses can be summarized as follows:

procurement:
time spent traveling to and from a source
time spent searching for a source
time spent evaluating material at a source
energy expended in transporting material – under various forms – to a site

core preparation and blank production:
increasing labor effort as cores become smaller or if they are of poorer quality
increasing lack of control over fracture
increasing chance of failure to produce suitable blanks

blank selection for tool production:
increasing lack of suitable blanks as materials are of poorer quality
more time needed to shape more elaborate tools (i.e., those with higher shaping intensity)

tool use:
if material is soft, more frequent resharpening may be necessary
poorer quality material may cause tools to break more easily (due to contact fractures)

The model explores the relationships between the four components defined above (quality, availability, procurement costs, labor costs). It attempts to predict how quality and abundance affect these costs. It should thus be possible to predict what kinds of strategies are expected within different raw material contexts.

Procurement and reduction strategies also have benefits associated with them. The *procurement benefit* is defined as the satisfaction of raw material needs for a given technique. That is, the optimal relationship, the best quality material for that technique, is achieved. The *reduction benefit* is defined as the production of useable blanks and pertains equally (if obviously) to the first useable blank as it does to the last blank produced at maximum potential. Within a specific raw material context, the optimal strategy need not necessarily be one in which materials are reduced to exhaustion, for example, when material is abundant.

To summarize, quality and abundance are two aspects of raw materials the maximization of which reduces pressures on the raw material economy. When available materials are of good quality and abundant, there is no need for strategies to conserve raw material. Procurement and labor costs are aspects of the *chaîne opératoire* which should be minimized. A high procurement cost reflects a decreased ability to obtain the necessary material while a high labor cost reflects a decreased ability to produce suitable blanks from a core of given material. Procurement and reduction benefits are the outcome of the interaction between aspects of raw materials and strategies of procurement and reduction.

The optimal strategy in a given situation will be one that considers the specific conditions of the range of variability in quality and availability of raw materials, both locally and non-locally, and then chooses procurement and reduction strategies that minimize procurement and labor costs, while maximizing the benefits. A distinction can be made between a generalized economy, where there are few or no constraints on choices made, and a specialized economy, where quality and availability exert increasing pressure on choices as sources of good quality material become more and more distant.

When local material is both of good quality and abundant, as at Maisières Canal and Huccorgne, the status of non-local material is irrelevant. Here, quality and availability exert little or no pressure on the structure of the assemblage. Material is suitable for any reduction technique and for any types of tools. When local material is of poorer quality, or when flint sources are more than 5 km distant, both quality and availability begin to exert pressure to cause differential exploitation of a range of raw materials in the assemblage. At Goyet and Spy, the nearest flint sources are 20-40 km distant and local materials include chert, quartzite and sandstone, typically in the form of waterworn cobbles. At Trou Magrite, the nearest flint is at least 60 km distant, but limestone is locally available and abundant, along with cherts and quartzites on the plateau above the site. It can be seen that when quality and abundance needs can be met, their influence on assemblage variability and the relationship between material and technique become negligible. If one or both needs are not met, specialized strategies come into play to compensate for the pressures exerted in order to maximize return. It can also be seen that the presence of such pressures convert raw material from what can be seen as an inexhaustible resource to a finite resource. When good quality, materials are readily available and abundant, there is no pressure to maximize returns. When they are not readily available, it is necessary to use strategies which most efficiently utilize the available material.

Under any conditions, there may be differential selection of blanks, based on blank morphology, to produce different kinds of tools.

POTENTIAL STRATEGIES WITHIN A LITHIC ECONOMY

Table 2.1 is a non-exhaustive list of behavioral strategies, ranked according to time and energy investment required. Choices made from the range of potential strategies are not constant across space and time, but vary in response to the raw material context and technological needs. In this way, time and energy expenditures are minimized *within certain constraints*. What is appropriate at one place and/or time may be inappropriate at another. It should be noted, however, that some strategies may be roughly equivalent in rank (e.g., logistical and embedded procurement), and also that it is often not possible to distinguish between them archaeologically.

1) procure and use locally available material
2) transport of non-local material from a previously occupied site to the study site a) in unreduced form b) as prepared cores c) as prepared blanks d) as finished tools
3) logistical trips from study site to raw material source to obtain (and possibly reduce) material a) in unreduced form b) as prepared cores c) as prepared blanks
4) embedded procurement (collection of raw material while engaged in subsistence activities) a) in unreduced form b) as prepared cores c) as prepared blanks
5) increase intensity of reduction for non-local materials, thereby a) producing smaller, but more, blanks (cores, which would otherwise have been discarded before being exhausted when material is abundant, are here reduced to exhaustion) b) lowering the minimum blank size requirement (blanks deemed unsuitable when material is abundant, are now selected for retouch)
6) differentiation between materials for different techniques to maximize the number of useable blanks from good quality material
7) differentiation between materials to produce different types of tools (e.g., opportunistic tools versus more deliberately or intensely shaped tools intended to be curated) Also, tools varying in function may require different kinds of materials.
8) increased intensity of tool use: resharpening tools, reshaping broken tools; in sum, curating finished tools as long as possible
9) modify techniques of reduction to correspond to local conditions, e.g., if material is too poor to produce blades/control fractures, alter reduction techniques to produce flakes, where control over blank shape is less important

Table 2.1. Potential strategies within lithic economy (non-exhaustive), ranked by time and energy investment.

1) The exploitation of local material has the lowest time and energy expense for procurement, but quality of such materials must be evaluated in terms of suitability for reduction techniques used. If local material is of poorer quality than desired, the decision to exploit such material must be weighed against the distance to the nearest source of better quality material. If this distance is too great, the local material may be used despite its relatively poorer quality.
2) Transport of material from a previously occupied site to the study site would generally be transport of an active tool kit, including cores in active use, blanks and tools. Procurement expenses have already been "paid" at the earlier site.
3) and 4) Logistical and embedded procurement strategies are undertaken to provision the site currently occupied for both subsistence (hunting and gathering) and domestic activities, to supplement or replace material transported from a previously occupied site.
5) As distance increases from site to lithic source, material procured previously (strategy 2) and material procured to provision the site (strategies 3 and 4) will be more intensely reduced in order to maximize the number of blanks (and therefore tools) obtained. Labor expenses may increase as cores become smaller and more difficult to work, and tools may be less effective when they are made on smaller blanks, but procurement costs are minimized.

6) Similarly, as distance to good quality material increases, reduction techniques which produce more blanks per core (e.g., prismatic blade technology, bladelet technology) may be applied to good quality material, while flake technology is applied to poorer quality materials.
7) The use of different techniques on different kinds of raw materials permits good quality material to be reserved for certain tool types, particularly those requiring greater shaping. Poorer materials can be used for simpler tools, or for those tools which can be used and discarded after a short period of use.
8) As distances increase, it becomes necessary to maintain tools, to resharpen or reshape them into other tool forms, rather than discarding them. Again, this has the effect of maximizing the use life of the material and minimizing procurement costs.
9) At the most distant sites, where local material is of poorer quality and good quality material is too distant to exploit to provision the site, certain techniques become difficult to apply and other techniques, such as flake technology, are utilized.

OTHER BEHAVIORAL STRATEGIES

Other behavioral strategies result in modification of the specific conditions under which procurement and reductions strategies are determined. Some, such as increasing intensity of reduction and use, can be seen as compensatory strategies in response to specific conditions. Others have a more substantial impact on the overall organization of the hunter-gatherer group. These include changes in mobility strategies, such as increasing mobility within a territory or increasing the territory itself, and transport of prepared cores, semi-finished products, and tools. The second implies a degree of planning as opposed to opportunistic utilization of local resources and doing the best with what is available. Planning ahead or a contingency strategy prepares for future needs without having to rely on what is potentially available locally.

Site selection. One behavioral strategy would be to select sites strictly on the basis of the presence of local sources of good quality raw material. A generalized economy would then be the optimal strategy because there are no restrictions on choices of reduction techniques, etc. To determine whether such a site selection strategy was operating, it is necessary to observe the range of potentially available materials in a catchment area around each site (defined as roughly a one-hour walk from the site, or around 5 km) and the proportion of local and non-local materials, in order to determine if sites are situated where both quality and abundance pressures are minimized. If lithic resources were the only consideration in site selection, site location would be the only strategy necessary to minimize such pressures; sites would be always found near flint sources. In reality, numerous other factors more important (more directly relevant to survival) than raw material needs contribute to the process of site selection. These include need for water, shelter, fuel and the presence of subsistence resources, especially those which are migratory and/or seasonally available.

Intensity of reduction. Intensity of reduction refers to the degree to which a core is reduced, measured by the number and size of blanks produced. Increased intensity of reduction is a function of the balance between procurement and labor costs. If procurement costs are high, cores will be reduced more intensively.

Munday (1976) analyzed the size relationship between cores and debitage and the distance to sources for sites in the Negev (Israel). He argues that size of cores and debitage decreases as distance increases, thus indicating increasing intensity of reduction the further one gets from the source. This can be explained by the model: at places close to the source, the labor costs outweigh the procurement costs sooner and cores are discarded before being exhausted. As distances increase, procurement cost increases and it is less costly to continue to reduce the core than to obtain more material from the same source or to use a poorer quality material.

Intensity of use. Intensity of use refers to the degree to which a tool is used and resharpened before discard (Dibble 1985, 1988, Dibble and Rolland 1992, Rolland and Dibble 1990). Dibble (1985) observes that resharpening is a reduction process and that, as a tool is resharpened, its flake area decreases relative to platform area, which remains constant. An index of intensity is the ratio between flake area and platform area. Additionally, changes in the retouched edge angle and invasiveness of retouch are indicators of intensity, forming a continuum from low to high. He concludes that variability in Bordes' scraper types was due primarily to discard at different stages of use, rather than because they were discrete types. He further argues that the proportions of different kinds of scrapers in an assemblage reflect intensity of use: simple sidescrapers indicate low intensity while convergent sidescrapers indicate high intensity.

Mobility strategies. Mobility strategies all imply some degree of transport of various products and focus on including different sources of raw material within the mobility range. Here, a source is defined as being either an *in situ* geological locus or a secondary deposit, such as river terraces and slope erosion zones. Higher procurement costs due to increased mobility are offset by transport. If resources are obtained locally (with low procurement cost) in the ordinary course of movement and transported, then procurement cost becomes only the energetic cost of carrying products. At the actual place of reduction and use perhaps far from the source, the procurement cost would have been high; alternately, poorer quality materials would have been used if materials had not already been transported.

One strategy to ensure that material is available when needed is to increase mobility within a defined territory to more regularly visit flint sources. This can be observed archaeologically (assuming you have well-dated sites in a region) by documenting the relative proportions of different materials in assemblages through time. If a source is being used more frequently, its proportion will increase within assemblages. The range of actual materials used will remain constant. Mellars (1989a) notes that work in both France (Demars 1982, Geneste 1985) and in Central Europe (Hahn 1977, Kozlowski 1982, Svoboda 1983, 1988, Schild 1987, Roebroeks *et al.* 1988) shows a contrast between Middle and Upper Paleolithic procurement strategies for non-local materials. He states that the "significant contrast...seems to lie not so much in the *maximum* distances over which raw materials were transported...but in the relative scale on which these more distant sources were exploited" (Mellars 1989a:366, emphasis in original). This is also observable in other regions as well, such as Catalunya (e.g., Soler *et al.* 1990).

A second strategy to ensure material availability would be to configure the mobility range to include sources without necessarily increasing the size of the range. Archaeologically, this can be documented by observing the range of materials used in different assemblages from stratified sites. Distances shorten for procurement of some materials and increase for others; hence materials for which distances shorten should increase in proportion.

A third strategy would be to increase the mobility range in order to include additional sources within it. For example, if the territory is poor in lithic raw material, increasing the size of the territory will include a wider range of materials. Again, having materials available when necessary offsets the higher procurement cost. This can be observed archaeologically by documenting the range of actual materials used in assemblages through time. The range should increase as the territory increases.

Transport of products. The three strategies discussed above can all be evaluated by analyzing the raw material properties of a lithic assemblage. Mobility strategies imply the transport of products, which is itself a strategy to compensate for imperfect conditions at a new site. To determine if products were transported, and under what forms, it is necessary to use assemblage-specific information. Sourcing information for the raw materials of transported products is also very useful, but may not always be available. If it is available, then it is possible to analyze how far material has traveled, evaluate the intensity of use in relation to distance from source, etc. If exact sourcing information is not available, then it may still be possible to identify material as non-local, and thus transported.

To analyze transport of products, it is necessary to examine the non-local material in an assemblage. The most straightforward way of determining what was transported is to identify which stages of the reduction sequence are represented: initial core preparation, core reduction/blank production, tool production, tool recycling. For example, if only tools and resharpening flakes are present, one can infer that tools were transported to the site, resharpened and then discarded. The presence/absence of the different reduction stages can be used to infer at what stage of reduction non-local material was brought to the site.

QUALITY WITH RESPECT TO REDUCTION TECHNIQUES AND TOOL EFFECTIVENESS

For any Paleolithic time period or industry, prehistoric humans evaluated lithic raw materials in order to meet needs. Raw material needed to be of sufficient quality for 1) application of known reduction techniques (general flake, Levallois, prismatic blade, bladelet), and 2) tool effectiveness in expected activities.

Application of Reduction Techniques

For the first requirement cited above, the quality of material affects the ability to control fracture, to control the direction and force of fracture in order to produce the desired blanks. Non-Levallois flake technology, in this respect, is the most flexible and requires the least amount of control over the shape of the blank. Flakes of variable form and size are produced, from which blanks suitable for different kinds of tools could be selected. Almost any degree of quality is suitable for producing flakes, from quartz to flint. Levallois technology, in contrast, requires better quality material (Tavoso 1984, Boëda 1988, 1990, Van Peer 1992), and the elaborate method of core preparation helps to ensure that flakes of predetermined size and form (whether Levallois flakes, blades, or points) are produced. Finally, prismatic blade technology has the greatest need for control of fracture because the aim is to systematically produce long, narrow flakes (length $\geq 2 * $ width).

Raw material can be divided into two broad groups based on relative quality: 1) isotropic, fine-grained, few inclusions, and 2) orthogonal, coarse-grained, many or large inclusions. These characteristics affect the ability to reduce the stone.

With isotropic materials, the direction of fracture and shape of the blank can be more easily controlled (Cotterell and Kamminga 1979, 1987, 1990; Speth 1972; Tixier 1978; Tixier, Inizan and Roche 1980; Crabtree 1972; Luedtke 1992). *Homogeneity* of materials (fine-grained, absence of inclusions and flaws) permits the force of fracture to follow a certain direction without being deflected or slowed. Luedtke (1992:86) states that inhomogeneity results in “general unpredictability of flaking” and affects the controllability of fracture.

Other mechanical properties include strength, elasticity and hardness. *Strength* refers to the toughness or tenacity of the material and is a “measure of how much force must be applied to produce a fracture” (Luedtke 1992:87). Strength must be low enough to allow greater control of fracture but not too low so that the tool produced is effective. *Elasticity* is defined as “the ability to deform without a permanent change in shape" and affects the "ability of a material to resist unwanted fractures, such as end shock and hinge fractures " (p. 90). Finally, *hardness* is defined as "the resistance of a material to abrasion, scratching or penetration by an indenter" (p. 91). This affects the effectiveness of tools during use.

When collecting material, the raw material is tested and selected for mechanical properties so that only material of good quality is actually transported. There are two scales of assessing quality: variability between sources and variability within a source. The first is more critical in evaluating and time and energy expenses while the second is assessed after a source has been selected. Variability within a source can be easily tested with much less investment (e.g., breaking open a nodule, tapping for sound, producing test flakes).

In contrast, with orthogonal materials, there are inherent multiple structural planes which can arrest a fracture or deflect it so that the direction of fracture is less controlled. Coarse-grained materials contribute to deflecting the direction of fracture or slowing it. Greater force may be needed, but hinge fractures may also be more common. Large inclusions, which are commonly coarser-grained than the matrix, also contribute to deflection and slowing of the force of fracture.

When material is procured at a source, a process of selection must have certainly occurred, whereby unsuitable nodules/cobbles were rejected. Selection based on quality occurs within the variability of a single source. Additionally, selection based on quality also occurs between sources, for example, between local poorer quality and non-local materials of better quality. Here, procurement costs become a factor.

So, looking only at suitability for reduction techniques, lithic materials used prehistorically can be ranked by quality:

1) flint, phtanite, fine-grained quartzite (e.g., in Belgium, Wommersom quartzitic sandstone)
2) chert, medium to coarse-grained quartzite, sandstone, limestone
3) quartz

Flake technology can be applied to materials of all three ranks. Levallois and blade technology can be applied most easily to top-ranked materials, with more difficulty to materials ranked second. Quartz is relatively more difficult material to knap, although there are industries based on quartz even in areas where flint is available (albeit at a moderate distance), including quartz bladelets at the Mesolithic site of Vidigal in Portugal (Straus and Viera 1989).

Tool effectiveness

Tool use will not be specifically considered in this study but will be discussed briefly here, within the context of raw material quality. The main issues with respect to quality and tool effectiveness are: 1) sharpness of working edge for various activities (cutting, scraping, boring, etc.), 2) durability: how quickly a working edge becomes dull during use, requiring resharpening, and 3) brittleness: breakability during use (e.g., fracture upon impact, breakage under pressure).

First, the working edge must be suitable for performing a given activity (whether general or specific purpose). For example, one could create tools from a block of plaster, but the resulting tools would not be very effective.

Second, if an edge becomes dull quickly during use and requires frequent resharpening, the tool becomes exhausted more quickly and has a shorter use-life, since resharpening is also reductive. Such tools require more labor input and more time expense, during an activity, to maintain the tool.

Third, if a material is too brittle, it will break easily during use, essentially abruptly ending its use-life (or requiring further labor input to reshape it into another useable form). Brittleness dramatically affects the utility of projectile points (impact fracture, breakage of point tips) and perçoirs and burins (pressure fracture), among others.

In an archaeological assemblage with different types of raw materials present, we should expect to observe different types of tools produced on different quality materials, based on expected tool function. The same ranking can be made as for application of reduction techniques, however.

Blank shape is probably the most important aspect in tool effectiveness, where thickness can control for breakability, etc. In this way, the top-ranked materials are the most flexible for meeting tool effectiveness needs because blanks of different shape (long, thin blades, thick flakes, etc.) can be readily produced.