UNDERSTANDING PREHISTORIC STONE TOOL MANUFACTURE AND THE FORMATION OF ARCHAEOLOGICAL ASSEMBLAGES

By Albert M. Pecora, Ph.D.
2003

My dissertation: Abstract, excerpts, modifications, and additions

2002 *The Organization of Chipped-stone Tool Manufacture and the Formation of Lithic Assemblages*. Unpublished Dissertation. The Ohio State University.

Dissertation Abstract

My dissertation research addresses the relationship between the organization of prehistoric lithic tool production and the formation of lithic assemblages. For the purposes of this study, two technological variables are used to define the organization of chipped tool manufacture: (1) the level of biface manufacturing complexity, and (2) the types of transport stages used. A lithic transport stage is defined as the point within the manufacturing process at which lithic material is prepared for transport and the point at which the reduction process is resumed at a given location on the landscape. Biface complexity is defined as the relative intensity of biface thinning necessary to convert a piece of lithic material into a bifacial tool. Both variables have a direct impact on the distribution, density, and diversity of lithic artifacts on the landscape.

Following various models of mobility, lithic research over the past 20 years has focused on explaining lithic artifact patterning in terms of changing prehistoric mobility strategies. In other words, lithic technologies are viewed as a reflection of prehistoric settlement organization. These approaches treat settlement structure as a conditioning factor that influences the organization of lithic technology. In other words, lithic technologies are thought to play a *functional* role within a given settlement system. It is proposed in this study that prehistoric tool technologies and the resulting assemblages should not be treated as a reflection of settlement organization, land-use, or site-specific activities. Instead, lithic artifact patterning is first and foremost a reflection of how stone tool manufacturing and use strategies were organized.

Assuming that the organization of stone tool manufacture and use are culturally patterned, two general propositions can be advanced: (1) If the same technology, in terms of transport stage and biface complexity, is employed at two different locations on the landscape occupied for the same general purposes, then the lithic assemblages generated would be very similar, and (2) if a different technology, in terms of transport stage and biface complexity, is employed at two different locations on the landscape occupied for the same general purposes, then the lithic assemblages generated would be very different. If valid, it should hold that two different technologies employed at two different locations occupied for different purposes would have two different lithic assemblages. Assemblage differences would be the result of differences in the organization stone tool manufacture.

The importance of this research is that it develops an approach for identifying and understanding how prehistoric lithic assemblages are formed. It is these formation processes that create lithic artifact patterning over the landscape. Without the ability to identify and understand such patterning, more significant archaeological inferences related to regional and temporal prehistoric settlement structure, and ultimately changes in settlement structure, cannot be made. The lithic assemblage formation approach advanced in my dissertation provides the framework for using lithic data within established models of hunter-gatherer settlement organization.

LITHIC REDUCTION MODEL AND TRANSPORT STAGE MODELS

Following the principles outlined by Collins (1975), lithic tool production is modeled as a reductive process beginning with the selection of unaltered raw material and ending with the discard of exhausted lithic material (Figure 3.1). Exhausted lithic material refers to all lithic material that, for some reason, is no longer suitable for further reduction or use. The lithic reduction process modeled here involves six stages of reduction: (1) core reduction/flake blank production, (2) flake blank preparation, (3) biface blank production, (4) biface preform production, (5) notched/stemmed biface production, and (6) notched/stemmed biface maintenance. Transport stages are pauses or terminations in the longer reduction process. It is during these pauses that partially altered lithic material is transported from a location of procurement and preparation to a place(s) for further reduction, use, and discard.

Six transport stages are defined based on the segmentation of a general lithic reduction model (Table 1). These transport stages represent the point at which the manufacturing process is resumed from a given reduction stage within the manufacturing process. These do not, and are not, meant to reflect all of the possible prehistoric reduction systems (and the organization variation) employed in prehistory. Instead, these models reflect a general system of stone procurement, use, and discard for the purpose of illustrating trends that would be reflected by the segmentation of all lithic reduction systems. These also illustrate the reductive effects of the chipped stone tool manufacturing process and show the physical constraints imposed by such a reductive process.

The proposed transport stage models presented in Table 1 and Figure 1 reflect how lithic tool production might be organized in terms of biface complexity, reduction stages, and transport stages. Biface complexity is measured by the relative intensity of biface thinning necessary to convert a piece of lithic material into a bifacial tool.

Transport stages are based on the reduction stages, which represent a portion of the reduction process (i.e., core reduction, flake blank preparation, biface blank production, biface preform production, notched biface production, notched biface maintenance). Each transport stage represents a termination in the complete reduction process at which point lithic materials are transported for further reduction elsewhere. *Transport Stage I*, reflects the complete manufacturing process though the use and discard of implements, without interruption. On the other end of the continuum, *Transport Stage VI* reflects only the final stages of manufacture through use and discard. With this latter transport stage, finished, serviceable tools mark the point at which the manufacturing process resumes at a given location. The reduction activities involved in *Transport Stage VI* include resharpening, rejuvenation, and recycling. The middle transport stages reflect various points (reduction stages) from which the remainder of the reduction process is continued. These include flake blanks through maintenance, prepared flake blanks through maintenance, biface blanks through maintenance, and preforms through maintenance.

Table 1. Proposed lithic transport stage models.

Transport Stage	**Trajectory**
I	Unaltered raw material through the discard of exhausted tool
II	Flake blank through the discard of exhausted tool
III	Prepared flake blank through the discard of exhausted tool
IV	Biface blank through the discard of exhausted tool
V	Biface preform through the discard of exhausted tool
VI	Finished tool through the discard of exhausted tool

Axioms

1. The organization of stone tool manufacture in terms of transport stages is a major limiting factor in determining artifact distribution (geographic range). It is expected that lithic material transported at earlier stages would result in a greater distribution of artifacts. But, lithic material transported at later stages will reduce artifact distribution.

2. Artifact density (artifact quantity) is not directly related to occupation intensity, but is instead dependent on the transport stage employed over geographical space. In other words, it is expected that artifact density is proportionate to the level of biface complexity and transport stage employed at a given location. Earlier transport stages will generate higher quantities of debris in comparison to later transport stages. This is enhanced with biface complexity.

3. The organization of stone tool manufacture is a major limiting factor in determining artifact variability/diversity. It is expected that because earlier transport stages provide greater lithic material availability, a greater variety of artifacts could be produced. Later transport stages limit the range of possible artifact types and increase the likelihood of lithic material recycling and re-sharpening.

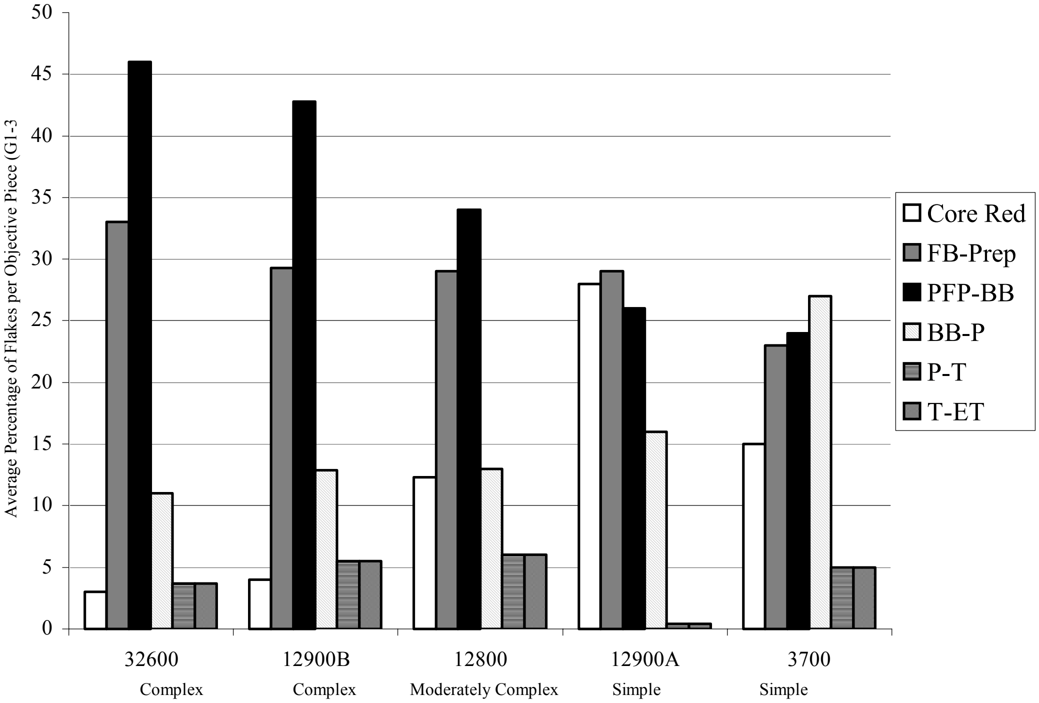

Figure 2. Average percentage of debris produced within each reduction stage for each experimental set.

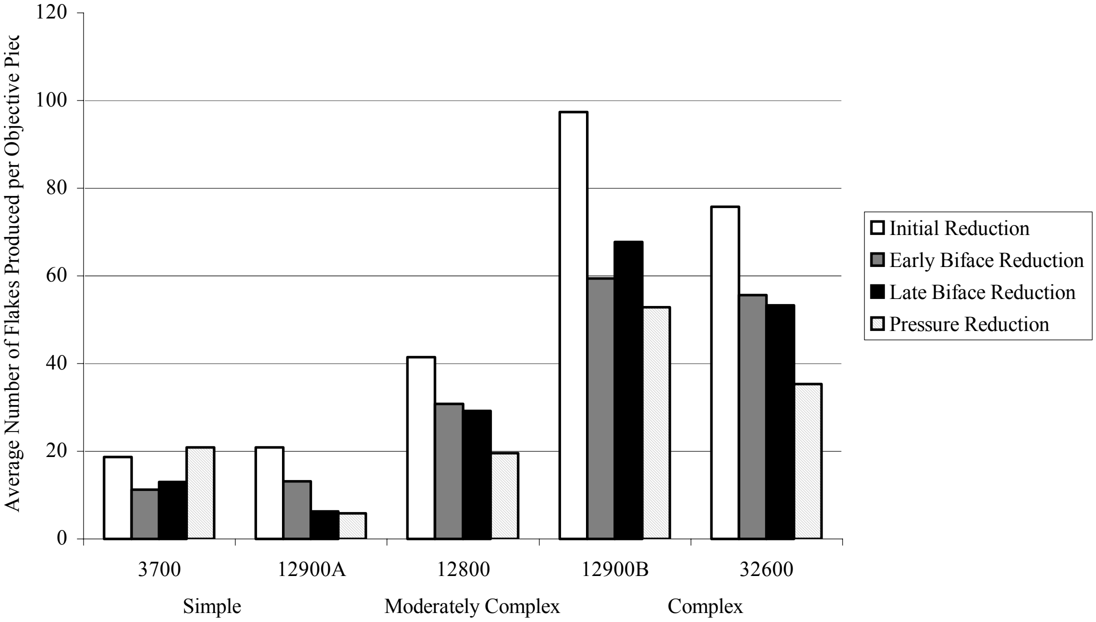

Figure 3. Summary of experimental data showing average number of flakes per objective piece for each relative reduction stage (G1-3).

MODELING LITHIC ASSEMBLAGE PROFILES FOR BIFACE COMPLEXITY AND TRANSPORT STAGES

Following the reduction transport stage models, it is possible to suggest correlating lithic assemblage profiles for assemblage distribution, density, and diversity (Table 2). These profiles assume that the quantity and quality of objects produced remain constant (e.g., occupation intensity and longevity). Assemblages generated at Transport Stage I (*TS I*) would be expected to have high artifact density and high artifact diversity. The reason for this is that *TS I* involves the entire lithic reduction process. This would naturally result in the production of greater quantities of debris and offer greater flexibility in the range of objects that could be produced. This would be especially true for complex biface reduction trajectories. *TS VI*, on the other hand, involves the further reduction of finished, serviceable tools. Debris production would be minimal, and the range of objects that could be produced is greatly limited. In sum, given that the number and quality of objects produced is constant, debris production and tool variability is greatly reduced from *TS I* through *TS VI*. This is simply due to the fact that each transport stage imposes greater limitations on the quality and quantity of lithic material available for reduction. The effects on debris production for each transport stage are illustrated in Figures 4-6.

Table 2. Expected lithic artifact assemblage from each defined transport stages.

Transport Stage	**Artifact Density (quantity) within sites**	**Artifact Distribution over the Landscape**	**Artifact Diversity within Site**
I	high	dense	high
II	high	dense	high
III	medium	moderately dense	high/limited
IV	moderately Low	moderately diffuse	moderate/limited
V	low	diffuse	low/limited
VI	very Low	very diffuse	very low

Table 3 illustrates the expected assemblage profiles based on biface complexity and the expected effect of early and late transport stages. The ratio of core reduction to biface reduction debris, biface tool diversity, biface tool recycling, and flake tools is considered. Lithic assemblages generated from simple biface reduction trajectories are expected to have high percentages of core reduction debris relative to biface reduction debris, low biface tool diversity, a low incidence of recycled biface tools, and a high incidence of flake tools. These trends are expected to reverse with biface complexity, where the proportion of biface reduction debris, biface tool diversity, and bifacial tool recycling are expected to increase. These expectations should be slightly exaggerated with late transport stages. In other words, the incidence of core reduction debris and flake tools should decrease, and bifacial tool diversity and recycled tools should increase with late transport stages.

The foundation for these expectations is based on manufacturing versatility, or manufacturing potential, which increases with biface complexity. The manufacturing potential for complex biface reduction is higher than simple biface manufacture for two reasons. First, complex biface manufacture results in the production of substantially more debris and more debris within the larger size classes. Hence, a given objective piece (e.g., flake blank, prepared biface blank, and biface blank), provides ample stone for additional tool manufacture (secondary tool manufacture). Second, the larger size of more complex biface forms from all stages provides more potential for tool recycling. Broken blanks, from all stages (flake blanks, biface blanks, preforms, and projectile points), can be more readily recycled into biface tools of various types. This manufacturing versatility is greatly reduced with simple biface trajectories simply because of the shear decrease in the amount of stone available for secondary tool manufacture and recycling.

The amount of core reduction debris relative to biface reduction debris is expected to decrease with biface complexity. It is more feasible (transport cost wise) to transport lithic material in a partially reduced form (e.g., flake blanks, prepared flake blanks, biface blanks, and preforms) than to transport large nodules and cores. Lithic debris generated from such a strategy is naturally dominated by biface reduction debris. The feasibility of transporting similar forms within a simple biface manufacturing system, however, is reduced by the limited manufacturing versatility and tool-stone potential. The apparent costs involved in the loss of manufacturing versatility linked to simple biface manufacturing systems, however, is potentially offset by greater versatility in the ranges of lithic sources that can be exploited. Complex biface systems require large pieces of lithic material. Simple biface systems can employ small pieces of lithic material, which may be more evenly distributed over the landscape. These sources also have greater utility for secondary tool manufacture. This potential should increase the distribution of core reduction debris relative to biface reduction debris.

Table 3. Expected Artifact Assemblage Profiles for Biface Complexity for Early and Late Transport Stages (TS).

Biface Complexity	**Core Red. Debris : Biface Red. Debris**	**Biface Tool Diversity**	**Recycled Biface Tools**	**Flake Tools**
Simple				
Early TS	High	Low	Low	High
Late TS	High	Low	Low	High
Mod. Complex				
Early TS	Moderate	Moderate-Low	Moderate-Low	Moderate
Late TS	Low	High	High	Mod. Low
Complex				
Early TS	Moderate-Low	Moderate-Low	Moderate-Low	Moderate
Late TS	Very Low	Very High	Very High	Low

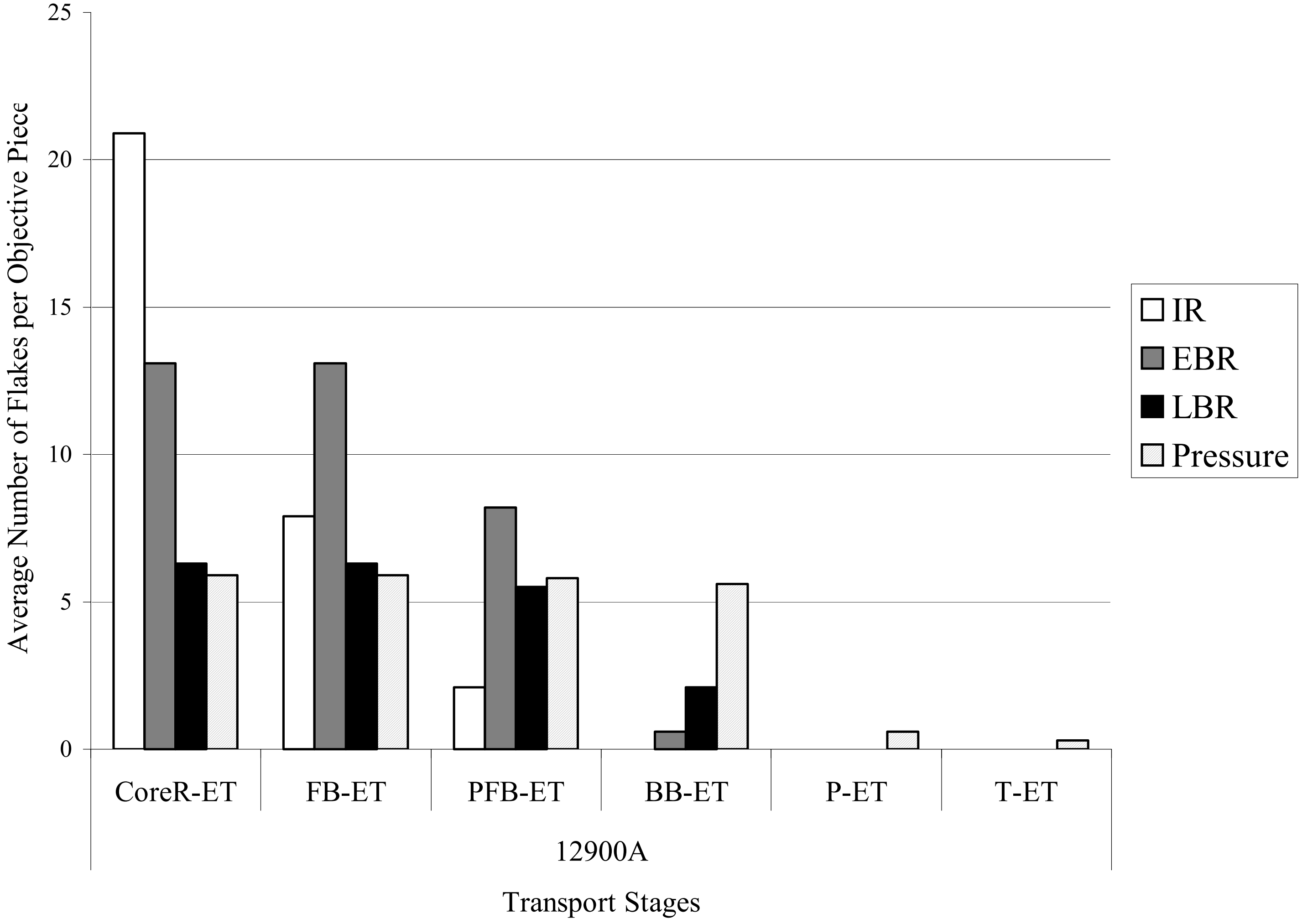

Figure 4. Relative reduction stage profiles for each transport stage from simple biface reduction.

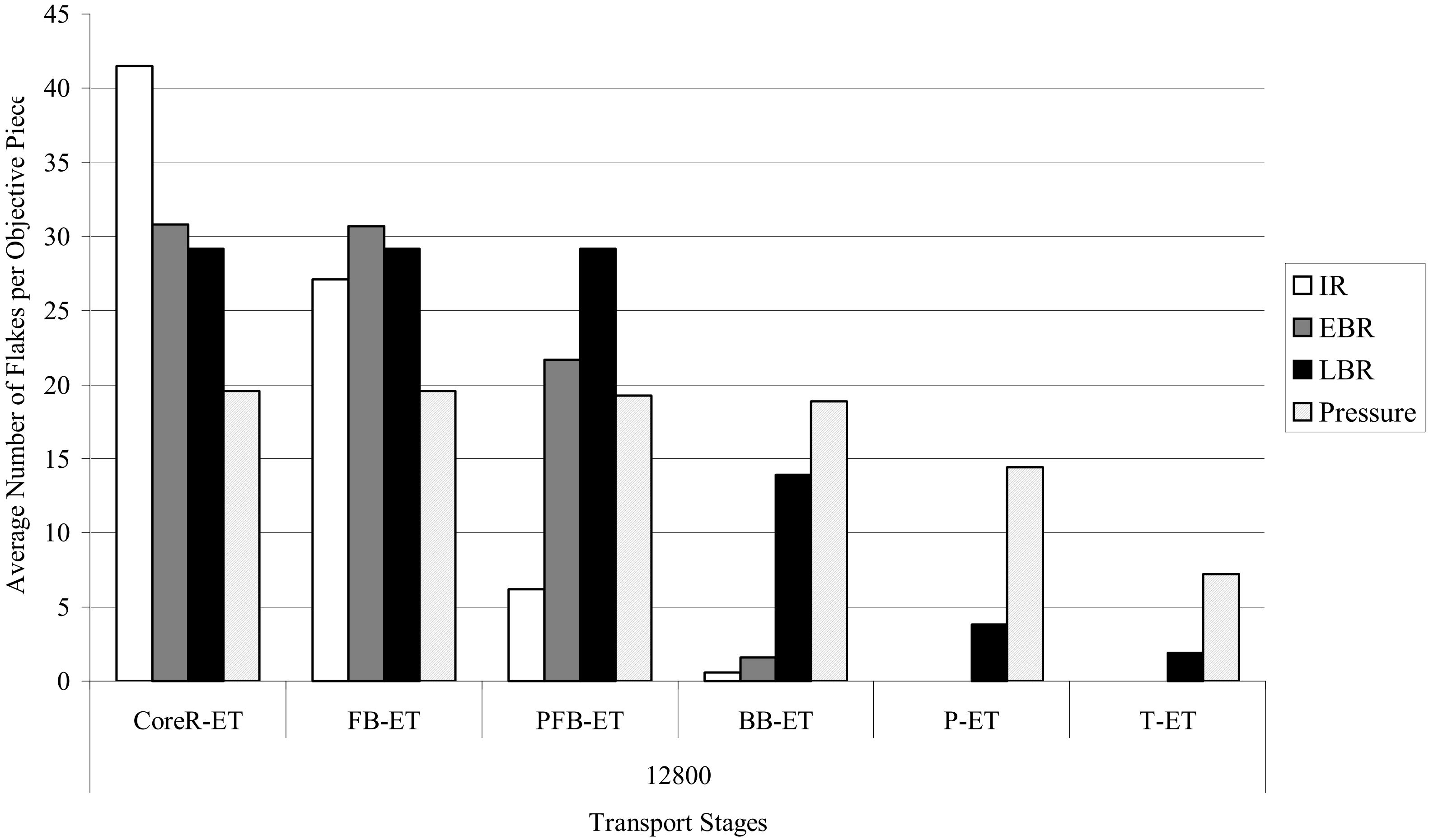

Figure 5. Relative reduction stage profiles for each transport stage from moderately complex biface reduction.

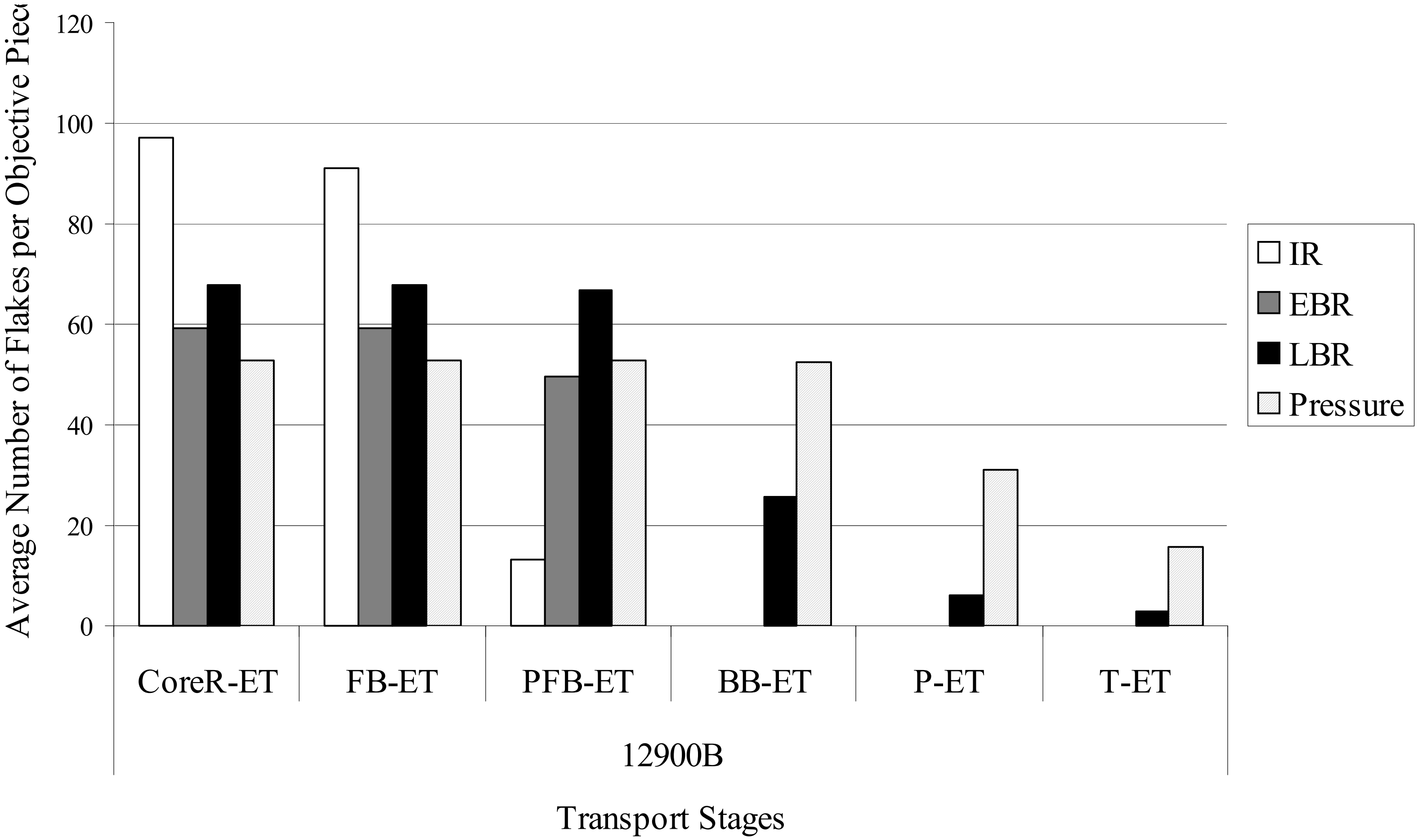

Figure 6. Relative reduction stage profiles for each transport stage from complex biface reduction.

Figures 7 and 8 illustrate lithic reduction stage profiles from eight archaeological sites in Licking County, Ohio. These sites are all located on similar landforms away from major drainages. Sites 33Li182, 33Li183, 33Li185, 33Li195, and 33Li196 are located in the Buckeye Lake region. The reduction stage data show middle transport stages in the 33Li182, 33Li183, and 33Li185 assemblages, especially with the Vanport flint (Figure 7). The assemblages from 33Li195 and 33Li196 reflect earlier transport stages, especially with the Upper Mercer flint.

Sites 33Li1291, 33Li1292, and 3Li1301are located approximately 6 miles northeast of Buckeye Lake. The reduction stage profiles reflect very early transport stages in the assemblages from all three sites.

In sum, both sets of assemblages have very different lithic reduction profiles. I doubt that this is a reflection of anything other than the form in which tool stone was introduced to these site (Transport Stages). Sites 33Li1291, 33Li1292, and 3Li1301are located within relatively close proximity to Upper Mercer and Vanport outcrops. It is very likely that the proximity to these flint sources facilitated the use of early transport stages.

Sites 33Li182, 33Li183, 33Li185, 33Li195, and 33Li196 are located further from known flint sources. Because of this, partially altered flint (later transport stages) was introduced to these sites.

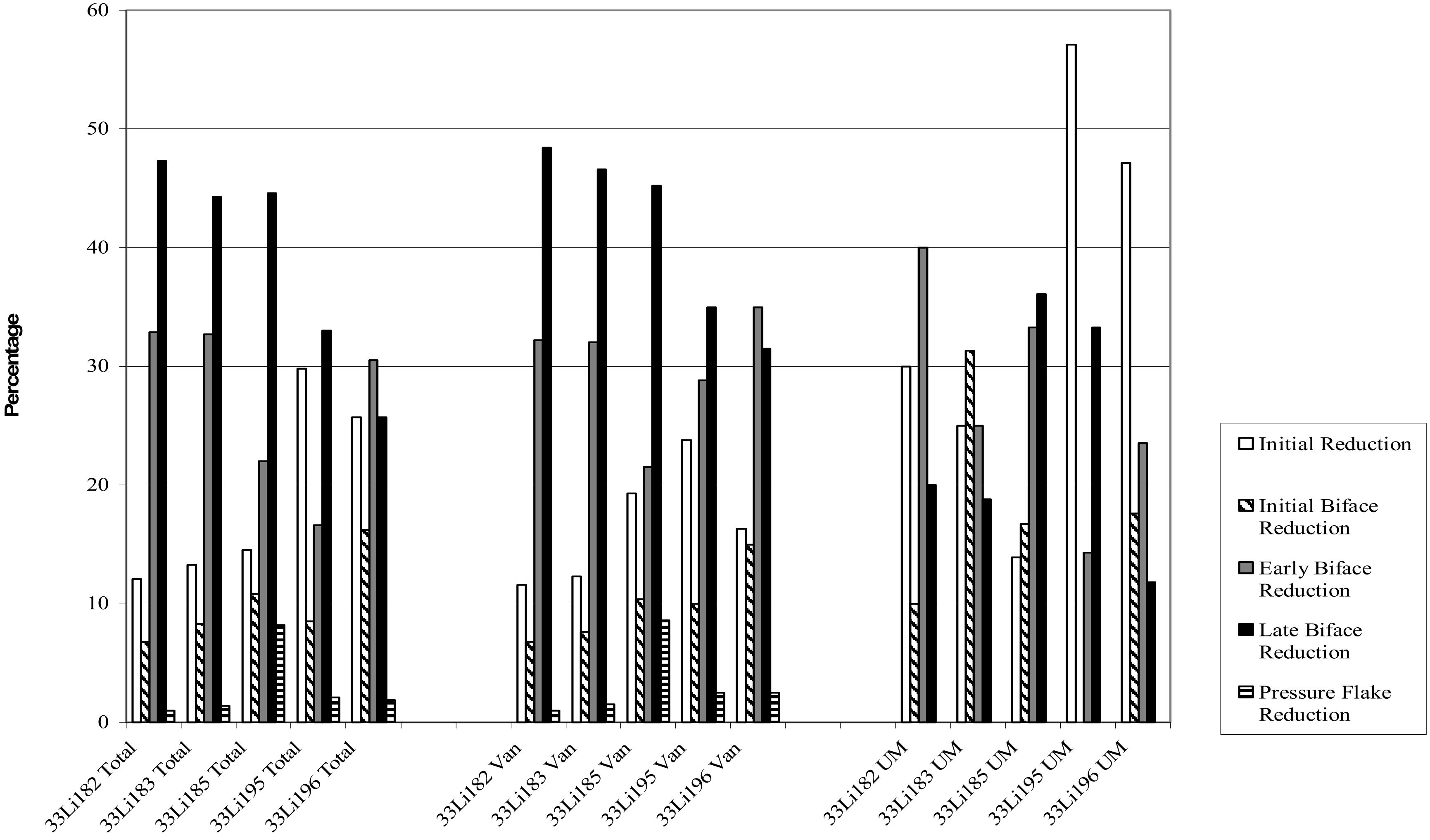

Figure 7. Bar graph illustrating the percentages of each lithic reduction stage for each flint type from 33Li182, 33Li183, 33Li185, 33Li195, and 33Li196 in Licking County (Pecora et al. 2004a).

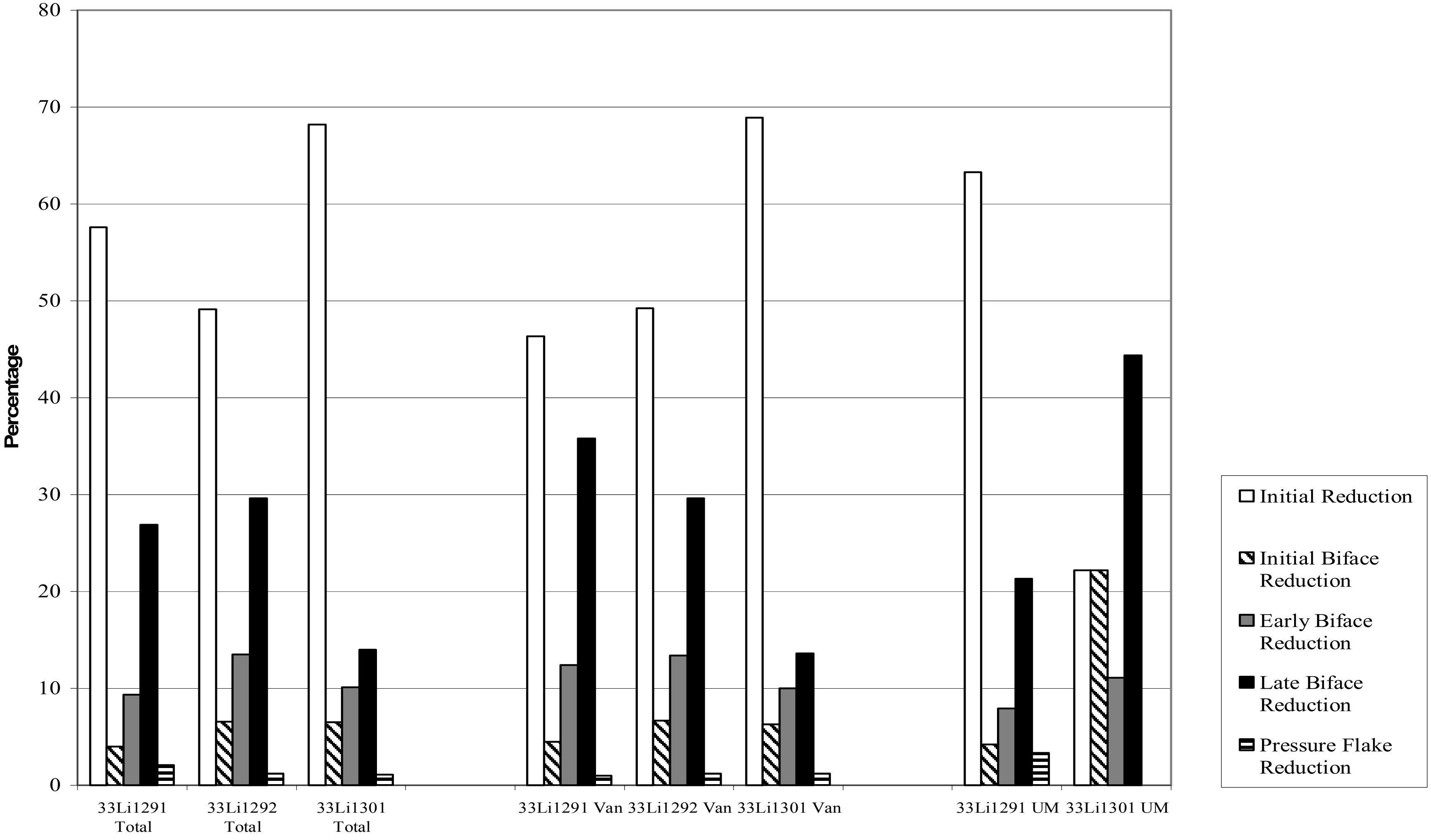

Figure 8. Bar graph illustrating the percentages of each lithic reduction stage for each flint type from 33Li1291, 33Li1292 and 33Li1301 in Licking County (Pecora et al. 2004b).

WHY USE A TECHNOLOGICAL APPROACH?

As I write this I can hear the screams from lithic technologists around the world (or at least those who read this), but chipped stone tool manufacture in the Ohio Valley is designed for the manufacture and use of bifacial projectile points. With the exception of a few other formal tool technologies (e.g., Middle Woodland Bladelet Technology), the primary technology is oriented towards the manufacture of projectile points. If this is incorrect, we should expect a series of other formal tool typologies.

Other chipped stone tools are secondary technologies. That is, they are made from debris generated from the projectile point reduction sequence. Frequently, broken and exhausted projectile points are recycled to be used as other tools. In some cases, this involves drastic physical modification, and in others, projectile point recycling involves little or no physical modification. Other tools may be made from smaller flakes generated during Initial Reduction and Late Biface Reduction. That is, tool blanks may be salvaged from the earlier stages of projectile point manufacturing sequence.

My dissertation demonstrates that the organization of stone tool reduction has a huge impact of the formation of lithic assemblages. The literature is replete with behavioral explanations for why lithic assemblages look the way they do. The explanations are often very complex and frequently contradictory. I think that most lithic assemblage variability is simply a reflection of how the reduction process was organized in terms of Transport Stages and Biface Complexity.

Lithic assemblages generated by people who used small, triangular projectile points (simple biface reduction) will always look very different than assemblages generated by people who used large, broad, dart points (complex biface reduction).

Likewise, lithic assemblages generated from early transport stages are always very different than assemblages generated from late transport stages.

The technological attributes used in my approach are based on physical constraints imposed by different stages of lithic reduction. Technological flake attributes that condensed into my Initial Reduction stage, are limited to attributes that cannot and do not result from the detachment of flakes from bifaces. That is, the systematic detachment of flakes with the technological attributes in my Initial Reduction stage cannot result in the creation of a biface and they cannot come from a biface. This is also true for each of my consecutive reduction stages (Initial Biface Reduction, Early Biface Reduction, Late Biface Reduction, and Pressure Flake (Biface) Reduction.

I was once asked by the commentator at a lithic technology symposium if I could REALLY? distinguish four stages of biface reduction. My response is, those flake attributes with each reduction stage are very different. One cannot systematically detach Late Biface Reduction debris from anything other than a biface at this stage. Initial Biface Reduction debris cannot be detached from a biface, but the systematic detachment of such debris will always result in the formation of a piece of flint with a biface edge.

Likewise, it is impossible to detach Early Stage Reduction debris from a fully thinned, late stage biface.

WHAT IS THE USE IN DEFINING "TRUE" REDUCTION STAGES?

Lithic analyses that rely on size or other morphological attributes frequently fail to distinguish between technological attributes. Most CRM reports in Ohio use lithic classification schemes that confound multiple technological attributes. The results infrequently "inconclusive" spatial analyses and the identification of lithic reduction trajectories that tend to look the same. In many cases, such reports identify reduction trajectories that reflect the opposite of what they reflect from a technological perspective. For instance, the assemblages from 33Li1291, 33Li1292, and 33Li1301 (Figure 8) were originally interpreted to represent the middle and late stages of tool reduction. My reanalysis of these assemblages identified few technological correlate to the middle and late stages of reduction.

Understanding the technological source of lithic assemblages is essential for both inter- and intra-assemblage comparisons.

Flake Size??

Folks, flake is not a technological attribute for inferring reduction stages. It means very little other than description. Complex biface reduction trajectories, however, do produce more large debris than do simple biface reduction trajectories. In both, however, most of the smallest size grades are produced during the earliest stage of reduction.

Cortex!!!

True, cortex is frequently detached from stone during the earliest stages of reduction. But the quantity of flakes with cortex within an assemblage is a reflection of surface area to volume. A grapefruit, for example, has a lower ratio of rind to flesh than a little clementine. If grapefruit size raw material is covered with cortex, then the ratio of flakes with cortex to flakes without cortex will be smaller than the ratio from clementine size raw material. Some flint (like Vanport and Upper Mercer) is bedded. The initial raw material from Vanport and Upper Mercer sources often has no cortex.

Heat Treatment

CRM reports in Ohio frequently talk about heat treated flint. A closer examination of the criteria used to identify heat treatment is actually criteria that should be used to identify burnt flint. Burnt flint is not a technological attribute. If flint is burned, it is no longer useful for stone tool production. Attributes such as crazing and pot-lidding is found on burnt flint, not heat treated flint. Heat treatment was used to improve the knapping qualities of some flints. Burning flint destroys the flint. Upper

Mercer and Zaleski are seldom if ever heat treated. Vanport is normally heat treated. All three get burnt.

I have also read in CRM reports that heat treatment was used to fracture flint to reduce it into a workable size (I heard this at the conference). If heat is applied sufficiently to fracture flint, the flint is ruined. This is one of those old ideas from the 19th century. This idea was dispelled in the early part of the 20th century.

STONE TOOLS

Technological Categories of Formed Artifacts

Formed artifacts are lithic artifacts with technological and morphological attributes indicating that they served as the objective piece from which flakes were removed. These items include cores, bifaces, notched and stemmed bifaces (projectile points), unifacial tools, and modified flakes. These artifacts are usually broken, heavily worked, damaged, and may represent the discarded/exhausted versions of actual tools or objective pieces (e.g., cores, blanks, and preforms) that were actually part of the manufacturing process. These artifacts seldom represent a useable form. For example, items identified as blanks and preforms are usually fragments or failed intermittent forms generated during the manufacturing process. In other words, a preform identified in the archaeological record may not be a useable preform, but instead may represent a form between the biface blank and preform stages. Flake cores are frequently exhausted (no longer useful for flake detachment), broken, or fragmentary. These artifacts do not reflect the types of cores actually used by a site's inhabitants, but instead represent what was discarded. Other items, such as projectile points or other tools, are usually broken, exhausted, or otherwise damaged. Like cores, biface blanks, and preforms, these artifacts most likely represent discarded forms, rather than useable tools. Exceptions to this, however, may be found in caches and burials.

In sum, cores, flake blanks, biface blanks, and biface preforms <u>are not tools</u>. There presence in archaeological assemblages represents the earlier stages of reduction. These usually have damage or breakage patterns that are indicative of manufacturing process rather than use. <u>Actual tools</u> include items such as projectile points, recycled projectile points (e.g. hafted scrapers, drills), bladelets, and marginally modified flakes. These artifacts are usually broken from use, heavily reworked/rejuvenated, and frequently have breakage patterns that are the result of use damage rather than damage from manufacturing errors. The presence of tools in archaeological assemblages is a reflection of tool use, rejuvenation, and discard.

The technological classification system used for formed artifacts in this study is adapted from Crabtree (1972), Flenniken (1987), and Pecora (2002). An attempt was made to eliminate functional implications in the nomenclature used to refer to these artifacts.

Cores

A core is defined as a piece of material that serves as a parent material for flake removal (Flenniken 1987). Flake cores may be biface cores; multi-, single-, and bi-directional cores; bipolar cores; and blade cores, to name a few. Archaeologically, these items tend to be exhausted and fragmentary. These conditions frequently create an amorphous appearance. That is, cores may be more systematically reduced prior to acquiring an amorphous appearance, at which point they tend to end up in the archaeological record. The purpose of core reduction is to produce flakes, which may be used unmodified or further reduced in to a variety of tools. Flake core technologies are frequently designed to produce flakes that can be subsequently reduced into projectile points.

Flake Blanks

Flake blanks are flakes detached from cores that are intended for reduction into prepared flake blanks, biface blanks, biface preforms, and ultimately bifacial tools. Unmodified flake blanks are indistinguishable from flaking debris in most archaeological contexts. Debitage and formed artifacts with remnant detachment scars from the ventral surface of flake blanks provide evidence of this reduction stage. Complete flake blanks are rare in the archaeological record, except in places where they were cached. Flake blanks may also be unifacially or bifacially modified to remove sharp and weak edges prior to transport. Fragments of flake blanks reflecting this process may be common in archaeological contexts.

Unidentified Biface Fragments

These are small irregular biface fragments that do not clearly possess characteristics of the other biface forms defined in this analysis. Most are probably biface blank or preform fragments, but may also include tools.

Early and Late Biface Blanks

A biface blank is a biface made from a flake blank, section, or tabular piece of material. Blanks are intended to be further reduced into preforms or directly into projectile points and other biface tools. This artifact type rarely occurs in a complete form, unless cached. Biface blanks are frequently fragments of bifaces aborted due to errors in the reduction process. Biface blanks are distinguished from tools by the lack of "finished" serviceable edges or other modifications indicative of some sort of use.

Early biface blanks tend to have very irregular, sinuous edges, are relatively thick, with large flake scar ridges. Early biface blanks made from flake blanks frequently have remnant detachment scars.

Late biface blanks have regular, relatively straight edges, are relatively thin, are relatively smooth and symmetrical in plan-view and cross section. No evidence of pressure thinning is present on late biface blanks, though their edges tend to be highly regularized and finely flaked.

Biface Preforms

A preform is an unfinished biface made from a biface blank, or flake blank. For analytical purposes, preforms are separated from late biface blanks based on the presence of systematic pressure flaking. Like flake blanks and biface blanks, preforms rarely occur in a complete, whole form. They are, however, frequently cached. Preforms are distinguished from tools by the lack of "finished" serviceable edges or other modifications indicative of some sort of use.

Unidentified Biface Fragments

Unidentified biface fragments are too small and fragmentary to classify. They may be fragments of biface blanks, preforms, and tools.

Biface Tools

Biface tools include items such as projectile points, drills, and knives. Projectile points (Notched/Stemmed bifaces) are completely formed and exhausted bifaces with either notched or stemmed hafting elements. These items usually represent the exhausted forms (rejuvenated, recycled, and discarded forms) of projectile points. Projectile points may be lanceolate points, dart points, or arrow points. Dart points are distinguished from lanceolates and other bifacial tools by the presence of barbs or shoulders that help hold the point in an animal's wound (Flenniken 1987). These points were designed to tip darts propelled by an atlatl, and would not function well as thrusting spears. Dart points may also have had secondary functions as cutting tools, and were frequently recycled into a modified or unmodified form to serve as a variety of tools, including drills, knives, and scrapers. Arrow points are similar to dart points in terms of how they function, but tend to be smaller and thinner. Smaller, thinner dart points and arrow points were seldom recycled for secondary tool manufacture and use.

Other biface tools are well-made bifaces that resemble finished and exhausted tools rather than blanks or preforms. Many of these may be projectile point fragments, recycled projectile points, or bifaces made specifically for non-projectile tools, or recycled projectile points (e.g. scrapers and drills).

Flake Tools

These artifacts are flakes exhibiting systematic modification along the flake margins. Such modification may reflect the working edge of the tool, but may also represent tool backing. These are usually formed of debris generated from biface manufacture and core reduction. It is rare to identify a technology oriented specifically towards the production of modified flake tools. Bladelet core technologies are an exception to this. Many of these items may not be tools, but instead may have been formed fortuitously from trampling and other post-depositional forces.

Some marginally modified flakes have very steep edges. These unifaces differ from other marginally modified flakes in that they are more uniformly and deliberately formed.