CHAPTER 1
DEBRIS, DEBITAGE OR TOOLS:
UNMODIFIED FLAKES AND CUTTING EFFICIENCY

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ABSTRACT
In most North American archaeological assemblages unmodified flakes are regarded as debitage or debris from stone tool production efforts. However, there is a great deal of ethnographic information that suggests unmodified flakes are not only effective as cutting and scraping tools, but that they are preferred as tools by aboriginal tool makers and users. In many circumstances contemporary tool users prefer unmodified flakes over retouched flakes and more formalized stone tools. This study examines the results of cutting efficiency tests conducted on unmodified and modified flake tools. Results from wood working experiments show that unmodified flake tools are more efficient cutting tools than modified flake tools, and that different kinds of lithic raw material may also be more effective and efficient for cutting than other kinds of raw materials. One implication of this study is that archaeologists may be overlooking an important tool category if they emphasize tool use activities based solely upon analysis of modified stone objects and not unmodified flakes. These results are particularly relevant for archaeological assemblages located away from primary and secondary sources of chippable stone used for tool making.

INTRODUCTION
This investigation of stone artifacts is focused upon data generated from controlled experimental studies. No excavated artifacts or site assemblages are applied to the results of these investigations. However, all of the methods, techniques, and results were explicitly formulated and gathered with lithic analysis and interpretations from the western region of North America in mind. In fact, all of the lithic raw materials and wood used in this investigation were from sources found in western North America.

This study describes a set of controlled experiments aimed at understanding the circumstances and variables related to functional efficiency of flake stone tools. I suggest wood whittling in the form of shaping, sharpening and notching sticks was a routine task for making tools such as arrow shafts, lances, snares, digging sticks, pegs, poles and many other practical items used by foragers on a daily basis. How were such tools made and what do we know about the efficiency of the stone tools used to make wooden items that must have been ubiquitous at aboriginal living areas?

The research presented here takes a new look at flake tools and systematically explores several variables of flake tool morphology and relates those variables to flake tool cutting efficiency. All cutting and whittling experiments were conducted on wet wood in the shape of stems or pegs of uniform size. In this sense the results of this experiment are relatively narrow and related to a single material and a single action-whittling. However, I feel that holding this variable constant has provided important clues in understanding not only the parameters of cutting efficiency but it has also provided information about changes in efficiency over the use-life of flake tools. The results of this study are interpreted within the context of technological organization of stone tool production and use. Ultimately, results from these experiments can be applied to sites from throughout western North America.

BACKGROUND ON FLAKE TOOL USE
In the summer of 1975 I participated in an experimental archaeology project at Virginia Commonwealth University directed by Dr. Errett Callahan. That project involved a group of student archaeologists making and using primitive technology and foraging in the eastern woodlands along the banks of the Pamunkey River for six weeks. As the trapper of the group I prepared snares by stripping hickory bark for cordage and cutting, sharpening and notching snare pegs from the same green hickory saplings—all with flaked
stone tools. When I brought the first trapped groundhog (Marmota marmax) back to our camp, Dr. Callahan proceeded to remove a series of flakes from a large bifacial core. After removing a dozen or so, he selected one flake about an inch and a half long and proceeded to skin, clean, and disarticulate the marmot. After completing the task he held up the flake he used and proclaimed that, “...this was the most important tool for any hunter and gatherer.” At the time I didn’t think much of the event nor about what he had said. After all, it was clear to me that the biface he used to make to the flakes was a more valuable tool and it certainly had more time invested in its manufacture.

If we look more closely at the ethnographic record of tool makers and users there are similar trends in tool production and use to that described above. Tom O. Miller (1979) describes his experiences with the Xeta’ Indians in the jungle mountains of southern Brazil as they make stone tools for working wood. He notes, “Nheengo piled up the flakes and fragments that he considered useful, pushing aside the rejects and waste...Rather than choose flakes on the basis of overall form, the informants tried out the stones empirically, one after another, to determine the tools best suited for any particular task” (ibid.:402). There are several interesting and important observations made by Miller here. First, flake blanks were produced in quantity and then the tool maker selected from the group of flake blanks with an eye for particular tasks that were to be completed. This is similar to what Errett Callahan did when I brought the marmot into camp for dinner. Secondly, the tool maker was looking for suitable cutting edges to work wood on flake blanks. This suggests that sharp cutting edges were not produced from blank retouching, but instead selected from unretouched flake blanks.

Other descriptions of stone tool makers and users conform to this observation. Binford and O’Connell’s (1984) description of stone tool production by Jacob, an Alyawara tool maker, at a stone quarry provides insight into the kinds of tools used for cutting tasks. “Jacob explained that the tools most commonly employed at camp were small flakes used for cutting up things. He noted that these need not be any particular shape, only fresh and sharp” (1984:418). Sharp flake blanks were one of the tool types Alyawara tool makers transported from the quarry back to their camps. “The men stressed the fact that they should be very careful in preparing flakes for transport and in transporting blanks from the quarry” (Binford and O’Connell 1984:421). Again, the notion of selecting and keeping sharp unmodified or un-nicked edges is important for flake tool blanks.

Brian Hayden’s (1977) experiences with stone tool makers and users in the Western Desert of Australia adds additional support to the notion that unmodified flakes were purposely selected for wood working activities over modified flake tools. He states, “...the biggest surprise, and ‘disappointment’, was the unbelievable lack, or rarity, or fabrication of what the archaeologist calls ‘tools’. At first, I saw Aboriginals using only unretouched primary flakes for shaving and scraping wood, and unmodified blocks of stone for chopping wood. ...Thus, only in special cases were flakes retouched. Instead of retouching primary flakes, the more common reaction of all informants was to look over other primary flakes for the work at hand, or to remove several more flakes from the core until a suitable one was knocked off” (ibid.179).

Richard Gould and colleagues (Gould et al. 1971) describe casual stone tool use for woodworking among Aborigines of the Western Desert of Australia. They note, “...a man will pick up an untrimmed flake of chert and, gripping it between thumb and forefinger, use it as a kind of spokeshave for scraping wood from the shaft or point of a spear. This happens when, for one reason or another, he does not have a hafted adze with him. Generally, the flake is discarded when the task is finished. In all cases, the rocks used as tools were completely untrimmed” (ibid.:163).

In each of these cases the stone tools selected for working wood are unmodified flakes. Recently, Chris Clarkson et al. (in press) conducted a series of experiments dealing with wood scraping. Surprisingly, his study shows that unmodified flakes were twice as efficient as modified flakes for scraping wood.

There have been many archaeological studies that suggest unmodified flakes as choice tools given specific circumstances. For instance, Parry and Kelly (1987)
demonstrate that “expediently made” flake tools are generally preferred over formalized stone tools in contexts where people are more sedentary. Other archaeological investigations have added to this scenario and indicate that availability of lithic raw material is an important factor in the selection of expedient technology over more formal technology (Andrefsky 1994; Bamforth 1986; Bamforth and Becker 2000; Holdaway et al. 1996). Other researchers have shown that transport of unmodified flake blanks are an optimal solution for available cutting edge versus carrying weight (Kuhn 1994; Surovell 2009). In other words, not only are unmodified flakes preferred as cutting tools as noted above, these kinds of artifacts are shown to be a more efficient choice of tool to carry when considering overall weight of transported materials and amount of reliable cutting edge.

Ethnographic accounts of flake tools used for wood working suggest that unmodified flakes are more efficient than modified flakes in some circumstances. The archaeological evidence suggests that unmodified flakes provide more efficient and reliable sources of cutting edges compared to heavier cores when raw materials need to be transported. However, what do we really know about the efficiency of flake stone tool cutting edges? Archaeological models are simple simulations of transport costs (weight) against amount of usable cutting edges. The few ethnographic examples we have available to us are simply isolated occurrences of tool makers using flakes for cutting wood. Such examples say nothing of tool efficiency-only that such and such tools were used. To address this issue I have designed a set of wood whittling experiments that compare a number of flake stone tool characteristics over the use-life of those stone tools used for whittling wood.

EXPERIMENTAL DESIGN

We know from the archaeological record that wooden sticks are used for a variety of tools from arrow and dart shafts, to digging sticks, to stakes for stretching hides, to snare pin switches and potentially hundreds of other tools and tool components (Aikens 1970; Heizer and Napton 1970; Jennings 1957, 1980; Strong 1969). All of these wooden implements had to be cut, shaped, sharpened and or notched-presumably by stone tools. Ethnographic accounts (noted above) indicate that unmodified flake tools were often used for wood working tasks. Because I know very little about the efficiency of working wood with flake stone tools I thought one effective strategy to learn something from a set of experiments would be to standardize the task and vary the flake stone tool characteristics, then explore those characteristics with regard to task efficiency.

In this experiment wooden sticks cut from a stand of Ocean Spray (Holodiscus discolor) were sharpened with many different flake stone tools. Ocean Spray is commonly used by indigenous peoples in the Pacific northwest to make arrow shafts and digging sticks because in grows relatively quickly and into straight stems with few branches (Daubenmire 1970). After drying, it also becomes very hard. Each stem or peg of Ocean Spray was cut into lengths of consistent diameter between 11.4 and 12.4 mm. One end of the peg was sawed into a 45 degree angle (see Figure 1.1A). The experiment consisted of sharpening the peg by whittling with flake tools in a uniform direction, slicing away from the hand with the hopes of maintaining the 45 degree angle or point of the peg (Figure 1.1B). Each peg was weighed before whittling began and the peg was weighed after every 20 strokes or slices. This provided consistent information on the amount of wood removed from the peg after each sequence of 20 strokes. Wood removed could then be used as a proxy for whittling efficiency. Each flake tool was used in this manner for a total of 500 strokes. A total of 49 flake tools were used in this manner over the period of several days.

The wooden pegs were air dried for 30 days after being harvested. This produced very dry and hard wood that was difficult to whittle. As such, each peg was soaked for 24 hours before whittling. This not only softened the wood for more effective whittling, but the uniform soaking time tended to standardize the wood density among the different pegs. Each peg was towel dried prior to whittling. During the whittling process the
pegs actually lost weight from water evaporation. However, this did not negatively impact the collected data on wood removal as evaporation of water occurred at a rate of approximately 0.01 gm per hour with slight variance depending upon how quickly each peg was whittled. No peg was whittled for more than two hours.

Of the 49 flake tools used 25 were made of Edwards Plateau chert and 24 were made of Glass Buttes obsidian. Approximately half of the chert and obsidian flake tools began with pressure flaked retouched cutting edges and the other half had unmodified edges.

Other characteristics recorded for the flake tools were maximum flake length, width and thickness, flake weight, length of flake cutting edge, and average cutting edge angle. The average cutting edge angle was based upon three measurements taken at the mid-point and at the approximate quarter-points of the cutting edge using a Number 17, General Tools MFG. CO. goniometer. To this day, I still feel there is quite a bit of error in measuring edge angles accurately on stone tools with any currently available instrument, but I do feel my average edge angles were at least accurate when compared ordinally when edge angles were grossly different. In other words, an average value of 33 degrees was consistently less than 50 degrees and that was consistently less than 73 degrees, and so forth. However, if two flake tools with very similar edge angles were independently measured multiple times I don’t believe one flake tool would consistently be measured with a greater or lesser average edge angle than the other flake tool. Table 1.1 shows the summary information for the experiment.

Table 1.1. Summary of Flake Data for All Flake Tools Used in the Experiment.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
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<tbody>
<tr>
<td>Maximum Flake Length (mm)</td>
<td>31.76</td>
<td>104.62</td>
<td>65.986</td>
</tr>
<tr>
<td>Maximum Flake Width (mm)</td>
<td>16.46</td>
<td>69.81</td>
<td>34.981</td>
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<tr>
<td>Maximum Flake Thickness (mm)</td>
<td>3.51</td>
<td>15.74</td>
<td>8.604</td>
</tr>
<tr>
<td>Flake Weight (gm)</td>
<td>2.5</td>
<td>48.2</td>
<td>18.12</td>
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<tr>
<td>Flake Use Length (mm)</td>
<td>11.24</td>
<td>40.87</td>
<td>23.047</td>
</tr>
<tr>
<td>Average Flake Edge Angle</td>
<td>29</td>
<td>54</td>
<td>40.653</td>
</tr>
<tr>
<td>Peg Diameter at Cut (mm)</td>
<td>11.4</td>
<td>12.38</td>
<td>12.022</td>
</tr>
<tr>
<td>Wood Removed (gm)</td>
<td>0.413</td>
<td>2.971</td>
<td>1.25</td>
</tr>
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</table>

Number Chert = 25; Number Obsidian = 24; Number Modified = 22; Number Unmodified = 27
The length of the cutting edge for each tool was marked on every flake used in the experiment. It is important to understand that the maximum length of the flake is different than the length of the cutting edge. I consistently used only the marked area for whittling wood. The marked cutting edge was also the location where the cutting edge angle measurements were taken. Figure 1.2 shows pictures of some the flake tools used before whittling began (note the marked areas for length of cutting edge).

**RESULTS**

During the course of conducting the experiment I felt confident that there were several characteristics of the flake tools contributing to cutting efficiency including length of the cutting edge, average edge angle, and size of the tool. These were characteristics that I informally inferred as important while whittling day after day. Surprisingly, none of these characteristics were significantly important for flake tool efficiency of whittling wood.

For instance, when length of cutting edge was compared against the amount of wood removed for each flake tool there was no correlation. In fact, the longest cutting edge of 4.1 cm produced about the lowest cutting efficiency ratings of 0.8 gm of wood removed on average per a twenty stroke segment. Figure 1.3 shows a scatter plot of flake cutting edge length against tool efficiency using this average measure. The $R^2$ linear regression value is 0.0009 showing no correlation. Average flake edge angle on the cutting edge of each flake tool was also charted against the average amount of wood removed. Figure 1.4 shows no correlation between efficiency of wood removal and average flake edge angle ($R^2 = 0.0058$).

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Figure 1.2. Examples of flake tools used in the whittling experiments. Background graph paper is partitioned into cm and mm blocks. Note the blade cutting edge locations marked in black.
Figure 1.3. Cutting efficiency measured by weight of wood removed (gm) compared against cutting edge length for all 49 flake tools. No correlation.

Figure 1.4. Cutting efficiency measured by weight of wood removed (gm) compared against average edge angle for all 49 flake tools. No correlation.
While whittling wooden pegs I felt that larger flakes were more efficient at wood removal, mostly because they were easier to hold in the hand and could be used with more force when slicing wood away. I had difficulty holding the very small flakes and as a result I imagined that larger flakes were more efficient for whittling. Flake size and the ability to hold and use the flake is a function of mass and shape. A rounded “nodule shaped” flake may have more mass and may be considered larger than a thin and elongated flake but its shape may preclude it from being an effective cutting tool. As such, I explored flake size by correlating different linear measures of shape against flake weight to determine a useful proxy for flake size. Figure 1.5 shows a couple of linear measures (length x width and width x thickness) graphed against flake weight. The linear measurements multiplied against each other provide a proxy for shape. When shape is compared to weight of flakes, in all cases flake weight correlates significantly against the linear measurement proxy for flake shape. This suggests that flake weight (at least with this data set) is a reliable estimator for flake size. Shott (1994) has also shown this to be the case using archaeological data on flake size.

Since flake weight correlates with flake shape to give a proxy value for flake size, I graphed flake size (and shape) against cutting efficiency as measured by the average amount of wood removed and again I was surprised to find that flake size had very little to do with efficiency of wood whittling (Figure 1.6). This figure shows that flake size and potentially shape are not correlated to wood whittling efficiency at least when sharpening sticks that are approximately 11.5 mm in diameter. Flake size may be important for more heavy duty wood whittling but this experiment focused on sharpening wooden pegs and flake size was not an important factor in whittling efficiency.

Since the metric variables recorded for flake tools were not effectively characterizing wood whittling efficiency I classified the flake tools by raw material type and the presence or absence of retouch on the cutting edge. This resulted in four flake tool types: unmodified chert, modified chert, unmodified obsidian, and modified obsidian. Figure 1.7 shows a proportional graph of the average amount of wood removed in 0.5 gram increments for the four flake tool types. Almost all of the modified obsidian flake tools produced less than 1.0 gm of wood removed. The unmodified obsidian flake tools and the modified chert flake tools had about equal amount of wood removed (20%) in the small size increment of less than 1.0 gm. The most striking element of this graph is that unmodified chert flakes had their highest representation in the greater than 2 gm increment. All other tool types had no or very few specimens in the largest increment category. These trends show that unmodified chert flakes are more efficient than modified chert flakes and any obsidian flakes for whittling wood, based upon amount of wood removed.

When these results are graphed to show the average amount of wood removed for each of the four tool types (Figure 1.8), unmodified chert flakes are almost twice as efficient at removing wood than modified chert flakes and unmodified obsidian flakes. And they are almost three times as efficient as modified obsidian flakes at whittling wood.

The whittling experiment also gathered information on the use-life efficiency of each flake tool type. Efficiency data were collected for every flake tool after every twenty strokes during the 500 stroke use-life of each tool. When the aggregate data for all flake tools are charted for stroke count and amount of wood removed (Figure 1.9), there is a significant trend associating more efficiency with early use of the tool. That is, the longer a tool is used the less efficient it becomes. The most efficient tools are those that were just made and had not been previously used. Those tools become less efficient as the number of strokes increases. Tools used during their first 20 strokes were the most efficient and tools used during their last 20 strokes (480-500 strokes) were the least efficient.
Figure 1.5. Flake shape characterized by width multiplied by thickness of flake tools and characterized by length multiplied by thickness (all in mm²). Both shape characterizations are positively correlated to flake mass (weight in gm).

Figure 1.6. Cutting efficiency measured by weight of wood removed (gm) compared against flake size using weight as a proxy for both size and shape. Very weak relationship.
Figure 1.7. Proportion wood chip weight in 0.5 gm increments for each flake tool type. Note the high relative proportion of unmodified chert flakes in the >2.0 gm increment.

Figure 1.8. Average amount of wood removed per 20 stroke increment for each flake tool type.

Figure 1.9. All flake tools combined; showing a decreasing amount of cutting efficiency as the tool are progressively used based upon number of strokes.
When these data are partitioned by the four tool types we have conformational data on efficiency of tool type against tool use-life. Figure 1.10 plots average efficiency of flake tool types by stroke increment for each of the four types. This graph shows that unmodified chert flake tools are more efficient at whittling wood than any of the other flake tool types. Unmodified chert flake tools can be used for approximately 280 strokes before their efficiency drops to the level of an unmodified obsidian flake tool that has never been used. The unmodified chert flake tools can be used for approximately 340 strokes before their efficiency drops to the level of modified chert or obsidian flake tools. Table 1.2 lists the linear regression values for each of the flake tool types graphed. All flake tool types show a significant and strong linear trend of efficiency loss over use life time. However, unmodified chert flake tools show a much stronger efficiency value than the other flake tool forms throughout total use-life.

### DISCUSSION AND CONCLUSIONS

This study indicates some interesting efficiency trends about flake tool use at least with regard to whittling wet or green wood. Unmodified flake tools are

<table>
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<th>Flake Tool Type</th>
<th>Linear Regression Equation</th>
<th>Correlation</th>
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<tr>
<td>Unmodified Chert</td>
<td>y= -0.0016x + 0.0633</td>
<td>R²=0.8902</td>
</tr>
<tr>
<td>Modified Chert</td>
<td>y= -0.0039x + 0.1245</td>
<td>R²=0.9608</td>
</tr>
<tr>
<td>Unmodified Obsidian</td>
<td>y= -0.0024x + 0.076</td>
<td>R²=0.925</td>
</tr>
<tr>
<td>Modified Obsidian</td>
<td>y= -0.0025x + 0.628</td>
<td>R²=0.8852</td>
</tr>
</tbody>
</table>

Table 1.2. Linear Regression Values for Each Flake Tool Type by Cutting Efficiency Loss During Use-Life.

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**Figure 1.10.** Cutting efficiency compared against tool use-life based on numbers of strokes for each flake tool type.
more efficient than modified flake tools. Unmodified chert flake tools are more efficient than unmodified obsidian flake tools. These patterns probably hold equally well for whittling and slicing materials softer than green wood such as leafy plant materials, animal hide and flesh. Harder materials such as dried wood, bone, antler and shell will probably reveal different patterns of efficiency than those produced here. I can envision cases in which retouched flake tools that have serrated edges would work effectively as saws for bone and hard wood. But sawing and whittling require two different kinds of cutting edges. Clearly, from this study retouched cutting edges that may be similar to serrated edges are not effective for whittling wood. Similarly, I can envision steep edged retouched flake tools such as end scrapers being useful for scraping soft materials such as cleaning sinew or hides without fear of inadvertently cutting through the materials. However, I’m confident that steep edged scraping tools are ineffective for use on wood or bone. Given the results of this experiment I would not expect retouched flake tools that have a serrated or steep edge to be used for whittling or slicing-they are just not as efficient as unmodified flake tools.

Previous archaeological studies of stone tool production and use models that link expedient flake tool use to sedentism and availability of raw materials (see Bamforth 1986; Kelly 1988; Parry and Kelly 1987) may be correct given what has been shown in ethnographic studies and this experimental study. That is, unmodified flake tools (or expediently made tools) may have been selected over modified flake tools and more formalize tools in general when available tool stone was present. If a good supply of lithic raw material were available for retooling there would be no reason for tool makers and users to even sharpen their flake tools when efficiency dropped. They could easily discard the inefficient flake tool and pick-up or strike-off a new sharp edged flake for use. 

Many of the models that characterize flake tool use and transport (Beck et al. 2002; Kuhn 1994; Surovell 2009) suggest that unmodified flake tools were selected for use because of optimal cutting edge relative to carry weight. Again, this may be correct, however, the information from this experiment suggests that there may also be a functional reason for selection of unmodified flakes for specific tasks. Unmodified chert flake tools are significantly more efficient than modified chert flake tools and any form of obsidian flake tool. These experiments suggest that aboriginal tool makers and users probably have been aware of the relative efficiency of various tool types and raw materials and could easily have selected specific tool types for the task at hand in much the same way that the Alyawara and Xeta’ selected specific flakes for their tasks (Binford and O’Connell 1984; Miller 1979). Retouched flake tools were probably a secondary choice for tool users when raw materials were abundant enough for easy replacement.

How about those situations when lithic raw materials for flake tools were not readily available or stockpiled for needed consumption? Those are the situations in which I would expect to see flake tools being retouched for longer use-life. In such situations tool makers and users cannot afford to discard flake tools simply because they are losing efficiency. Those tools would be used until their efficiency drops low enough so that resharpening is an effective means of increasing tool usefulness. Based upon these experiments, that drop would be at approximately 340 strokes on unmodified chert flakes. But even in those instances where lithic raw materials are abundant, archaeologists should not be surprised to find special function tools that are retouched such as steep edged scrapers for working soft materials. However, these need to be recognized as special function tools where the working edges are specifically crafted for a unique task. Such tools should not be calculated into optimality equations associated with tool use-life and retouch amounts.

In this study I suggest that wood working was an important component of forager life-ways and that the most efficient tool to whittle wooden implements was an unmodified flake of a durable raw material such as chert. Unmodified obsidian flakes could also be used but because obsidian is more brittle than chert it was not as efficient for whittling wood, but could have been used effectively for softer materials such as animal flesh.
Archaeologists working on sites or site assemblages that have readily available and chippable stone need to consider the possibility that “unmodified flakes” were not simply discarded debitage, but instead are flake tools that were used to perform a needed task and discarded as efficiency of task performance began dropping. Furthermore, a higher frequency of recognizable retouched flake stone tools on some sites may simply be a reflection of low raw material abundance and not some functional or task specific difference of the site. Because the lithic and wood raw materials were specifically gathered from the western region of North America this study was envisioned with this region in mind. However, I believe the results of these controlled experiments have much broader impact and can be applicable to investigations related to foraging societies from many places around the globe.

REFERENCES CITED


