Experimental Archaeology: Assessing Methods in Lithic Debitage Analysis

Eva Larson
Hamline University

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Experimental Archaeology: Assessing Methods in Lithic Debitage Analysis

Eva Larson

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for graduation with honors in Anthropology
from Hamline University

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Abstract

Although often referred to as ‘waste’ flakes, lithic debitage can provide a great deal of information about how past peoples lived and created their stone tools. While we can never have all the answers, lithic debitage analysis can help us fill in these historic gaps. This thesis employs lithic debitage analysis of nine experiments provided by expert flintknapper Dan Wendt to better understand early biface, late biface, and coreflake reduction techniques. Recording attributes including flake class, raw material, general size characteristics, platform grinding, platform lip, percussion bulb, and flake termination allow for a thorough and impressive dataset. Additionally, Wendt’s experiments have provided an opportunity to review and critique Hamline’s Archaeology Lab Lithic Waste Analysis Protocol, focusing on platform angles and dorsal flake scar counts. Analyzing these experiments helps us better understand the production stages and techniques of stone tool manufacture, as well as the role of raw material in attribute data collection. The resulting distinctions between reduction strategies lend themselves to later comparison and applications against debitage from archaeological pre-contact sites across Minnesota.
Introduction

Humans have been making stone tools for millions of years by reducing raw lithic (stone) materials to a variety of tools that could be used for hunting, building, farming, food preparation, and more. When reducing larger stone into smaller artifacts, lithic waste flakes are created as by-products and are often left discarded around the flintknappers’ workspace. This debris reveals valuable data for archaeologists to later discover. But what can this lithic waste tell us about an archaeological site? Archaeologists have used the analysis of stone tools to address big questions about humans and the human story: how past peoples lived, made a living, where they traveled, even how they managed their time. The process of flintknapping includes different lithic reduction strategies and time management in order to complete the desired tool.

In collaboration with my peer, Hannah Bergene, we sought to better understand these lithic reduction strategies—specifically, core/flake reduction, early biface reduction, and late biface reduction. We began combining our efforts during Hamline’s Summer Collaborative Undergraduate Research (SCUR) program in 2020 in order to grapple with what individual flake attributes could tell us about stone tool production. In early fall of 2020, we received a large assemblage of new debitage (collective flake) experiments from Dan Wendt, an expert flintknapper, created using the three reduction strategies in question. Our primary research goal, then, has been to utilize the lithic debitage provided by Wendt to determine how (or whether) these reduction strategies can be distinguished.

Lithic material preserves so well compared to organic materials that it is typically the best indicator of a site’s occupation, and analyzing lithic debitage can provide quite a bit of information about the past. These pieces of debris can reveal when, where, and how raw materials were used thousands of years ago to create tools and other valuable devices. For instance, were the raw materials found locally, or were they transported to the site from a more distant source? Attributes of flake morphology can inform archaeologists about manufacturing techniques and lithic reduction strategies. The evolution of stone tool manufacture may also be evident at sites with large enough assemblages that span a long enough period of time. Even where the spread of flakes was found across a site can indicate where flintknappers worked, which can extend to interpretations of labor organization among those who occupied the site. It is easy to become preoccupied with the details of the data, but it is imperative to return to the larger ideas the lithic debitage may contribute to the human story.
Background

*Experimental Archaeology and Middle-Range Theory*

As described by Kelly and Thomas (2013), information can be taken from contemporary observations to better understand the past. This concept is referred to as middle-range theory, wherein empirical data (observed archaeologically) is linked to human behavior. Lewis Binford, an American archaeologist, contributed to processual archaeology with his call for middle-range research in the 1960s. Doing so meant using modern analogies to understand the processes that created the archaeological record (Bradbury & Carr, 1995; Kelly & Thomas, 2013; Raab & Goodyear, 1984).

One way to implement middle-range theory, as demonstrated through my research, is through experimental archaeology. Lithic waste flakes were created by flintknappers who chipped away at larger stone materials (Shott, 1994). With the help of modern flintknappers, we can experiment with different lithic reduction strategies. Data from these experimental flakes can later be compared to debitage from archaeological sites. It is then possible to draw similarities to grasp the ways past peoples were creating their stone tools.

Throughout this research Bergene and I had the privilege to work with Dan Wendt, an expert flintknapper in Minnesota (see Fig. 1). He contributed greatly to this research by generating our large experimental collection for study. Wendt studied chemical engineering at the University of Wisconsin-Madison before delving into archaeology. As the president of the Minnesota Archaeological Society (MAS) and an archaeologist and lithic specialist, Wendt has spent over 30 years partaking in archaeological research throughout the Upper Mississippi Valley. Among many other projects, he has helped to create the Minnesota Historical Society’s lithic comparative collection – it is quite impressive! (Minnesota Archaeological Society, 2017). We are very grateful for his collaboration in this experimental work and for making our middle-range research possible.
 Flintknapping and Reduction Strategies

When examining lithic debitage, an important connection to make is with that of the source: flintknapping. Flintknapping is the shaping of stone through the process of lithic reduction to create tools (see Fig. 2). This is truly a skill that takes time and practice to achieve knapping success. For instance, it requires the ability and effort to control the way the rock breaks. Beginning with a piece of raw material, flakes are removed by striking the edge of this core—a process known as percussion flaking. The percussor can be a hard hammer (typically igneous or metamorphic rocks) or a soft hammer (typically a piece of antler). Pressure flaking is another method of flake removal, where the knapper applies direct pressure to an edge. This is commonly done later in the reduction process to sharpen or straighten the edges of finished tools (Crabtree, 1972; The Office of the State Archaeologist, n.d.).
Significant consideration must also be given to the role of raw material in any sort of lithic analysis. While a flintknapper’s choice of raw material is based on material availability, different materials also break in different ways (Bakken, 2011; Eren et al., 2014). Ideal materials for knapping are those with homogenous crystalline structures, rather than those that are coarse and grainy (Whittaker, 1994). Additionally, raw materials may be transformed into more workable pieces through heat treatment. This process thermally alters the raw materials by improving the crystalline structure (Bakken, 2015). The experiments in this research were produced with Grand Meadow Chert (GMC), Knife River Flint (KRF), and Oneota Chert, a variety of Prairie du Chien Chert. While all these materials can be found in Minnesota, lithic experts and contemporary flintknappers would describe the relative quality of these materials as quite different. Of the three, Oneota is of poor quality, whereas KRF is of the highest quality (Bakken, 2011; Wendt, 2014).

There are different methods for producing various stone tools. In the midwestern United States, the two primary strategies throughout the Holocene were to make bifacial tools or flake tools (Crabtree, 1972; Kelly, 1988; Whittaker, 1994). While Bergene and I are aware that these strategies are not exclusive and can overlap, the goal of this research is to distinguish between the core/flake strategy and the biface strategy through debitage analysis. Further, within the biface strategy, it is possible to distinguish between early and late biface reduction. The

*Figure 2: Flintknapping diagram (Stout & Chaminade, 2007).*
experiments provided by Wendt include a mix of both biface and core/flake approaches using a mix of raw materials (see Table 1). The following are the definitions of these reduction strategies:

**Biface Reduction.** Bifacial reduction consists of material being detached from both tool faces in opposing directions to shape a biface (Kelly, 1988; Whittaker, 1994). The biface “core” is made into the tool with this reduction method, although the flakes from the biface can also be used or made into tools, producing projectile points and other stone devices.

Modern flintknappers often distinguish between early and late stage biface reduction (Andrefsky, 2005; Callahan, 1979). Early stage biface reduction consists of the core being reduced to a rough biface. Typically, early stage debitage attributes consist of more cortex and generally larger flakes. The opposite is true of late stage biface reduction, which consists of further knapping the tool into a more refined biface (Andrefsky, 2005; Callahan, 1979).

Callahan’s (1979) description of stages 1–2 encompasses early stage biface, where the blank (cobble of raw material) is obtained and the outer edges are worked into a rough biface. Wendt considers Callahan’s (1979) stage 2 as a transition, then, to late stage biface reduction (stages 3–4). This is where a symmetrical outline is established while starting to thin the center of the tool (Callahan, 1979).

**Core/Flake Reduction.** Core/flake reduction consists of a piece of raw material being worked into a core and then knapped into flakes. The resulting flakes that are usable are then further reduced into tools (Callahan, 1979; Kelly, 1988). In this way, core/flake reduction can overlap with bifacial reduction—something I am trying to distinguish through debitage analysis. Essentially, the “core” in core/flake reduction is a source of flake blanks, whereas the “core” in biface reduction becomes the tool.

**Debitage Analysis**

The study of lithic reduction processes has evolved through the evaluation of morphology (flake form) and the creation of typologies (Flenniken, 1984; Johnson, 2019; Sullivan & Rozen, 1985; Whittaker, 1994). Different morphological traits and typologies became associated with alleged functions, which have then been used to describe ancient human cultures and behaviors. Ethnography and experimental archaeology can be great resources to understand lithic reduction technologies; however, they should be used carefully due to their potential to impact inferences of behavioral and cultural information (Flenniken, 1984).
**Flake Attributes.** The following defined flake attributes are essential for making inferences regarding lithic reduction strategies (see Fig. 3 illustration of flake morphology):

*Reduction Stage:* Reduction stage (i.e., early or late biface) was provided to us by Dan Wendt as supported by Callahan (1979). This attribute only applies to experiments of biface reduction, as there are no generic stages defined for core/flake reduction (Callahan, 1979).

*Reduction Type:* In this case, reduction type refers to whether the experiment was knapped using biface or core/flake technology. This was provided to us by Dan Wendt (2020).

*Flake Class:* Following Sullivan and Rozen (1985) and Hoffman and Seaberg-Wood (2020), flake class is determined by flake completeness and the presence/absence of multiple dorsal surfaces.

*Raw Material:* As previously noted, identifying raw material is useful due to the way different materials can be knapped. Further, it connects to social aspects regarding material procurement (e.g., migration, trade, etc.).

*Cortex Percentage:* Dorsal cortex refers to the outer layer of a rock formed by chemical or weathering processes (Shott, 1994). This attribute can offer insight into the stage of reduction, as the cortex is primarily on the outer layer of rock and must be removed first (Johnson, 2019).

*Size Characteristics:* Among the most reliably and consistently recorded attributes are size grade, length, width, thickness, and weight. While length and width measurements depend on the flake class, all relate to overall flake dimensions (Johnson, 2019; Shott, 1994). Because flintknapping (regardless of reduction strategy) is a reductive process, size characteristics can be useful for predicting the bifacial reduction stage.

*Platform Grinding:* Platform grinding is a form of abrasion on the striking platform surface. Andrefsky (2005) notes that grinding has been associated with biface reduction more than core/flake reduction.

*Lip:* A platform lip is exhibited at the base of the platform as a projection or overhang on the ventral side. This attribute can be related to the type of percussor used (Schindler & Koch, 2012).
**Bulb:** The bulb is also located on the ventral surface of the flake. It is created when the force is absorbed from the strike that detached the flake (Shott, 1994; Sullivan & Rozen, 1985).

**Flake Termination:** This attribute refers to the distal end of the flake and the way in which it comes off of the core.

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**Methods**

Bergene and I received nine lithic experiments from Dan Wendt in the fall of 2020, and we went on to perform our data collection between December 2020 and July 2021 (see Table 1). In doing so, we fully cataloged each experiment and recorded data on the aforementioned flake attributes: flake class, raw material, dorsal cortex percent, size grade, length, width, thickness, weight, platform grinding, platform lip, percussion bulb, and flake termination. In each experiment, Wendt labeled the flakes in the sequence of the flintknapping process, and we cataloged them in this order as best we could.

Table 1 provides a snapshot of each experiment, based on the Replication Log from Wendt (2020). Here, it is evident that most experiments are made of the poor-quality GMC using a moose antler (soft hammer). I added the starting cobble weight and biface stages to this table for later reference to flake counts per experiment. Additionally, it is worth noting that not all

---

![Figure 3: Attributes of a lithic waste flake (Morrow, 2016).](image-url)
experiments led to the successful completion of a tool. Experiments 2, 6, and 7 were bifaces that broke during the knapping process.

<table>
<thead>
<tr>
<th>Exp. #</th>
<th>Material</th>
<th>Source</th>
<th>Starting Weight (g)</th>
<th>Approach</th>
<th>Stage(s)</th>
<th>Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oneota</td>
<td>Spring Valley, WI</td>
<td>839.7</td>
<td>Biface</td>
<td>Early &amp; Late</td>
<td>Moose Antler</td>
</tr>
<tr>
<td>2*</td>
<td>Oneota</td>
<td>Louisville, MN</td>
<td>288.9</td>
<td>Biface</td>
<td>Early &amp; Late</td>
<td>Various</td>
</tr>
<tr>
<td>3</td>
<td>GMC</td>
<td>Grand Meadow, MN</td>
<td>210.4</td>
<td>Biface</td>
<td>Early &amp; Late</td>
<td>Moose Antler</td>
</tr>
<tr>
<td>4</td>
<td>GMC</td>
<td>Grand Meadow, MN</td>
<td>189.6</td>
<td>Core/Flake</td>
<td></td>
<td>Moose Antler</td>
</tr>
<tr>
<td>5</td>
<td>Oneota</td>
<td>Spring Valley, WI</td>
<td>144.9</td>
<td>Core/Flake</td>
<td></td>
<td>Moose Antler</td>
</tr>
<tr>
<td>6*</td>
<td>Oneota</td>
<td>Spring Valley, WI</td>
<td>2030.0</td>
<td>Core/Flake</td>
<td></td>
<td>Moose Antler</td>
</tr>
<tr>
<td>7*</td>
<td>Oneota</td>
<td>Spring Valley, WI</td>
<td>1191.8</td>
<td>Biface</td>
<td>Early</td>
<td>Hammerstone</td>
</tr>
<tr>
<td>8</td>
<td>KRF</td>
<td>Halliday, ND</td>
<td>209.9</td>
<td>Core/Flake</td>
<td></td>
<td>Moose Antler</td>
</tr>
<tr>
<td>9</td>
<td>KRF</td>
<td>Halliday, ND</td>
<td>198.9</td>
<td>Biface</td>
<td>Late</td>
<td>Moose Antler</td>
</tr>
</tbody>
</table>

Table 1: Experiment overview - Replication Log from Wendt (2020).
*Indicates biface broke during experiment.

**Data Collection: Attributes**

Before measuring any attributes, Bergene and I had to consider the reduction stages present. Wendt had divided bifacial experiments into “Stage X Flakes” and “Stage X Sweepings,” with most distinctions being stage 1–2 (early biface) and 2–3 or 4 (late biface) (Callahan, 1979; Wendt, 2020). We used a shaker screen to divide the sweepings into a macro fraction (greater than ¼’’), meso fraction (between ¼” and ⅛”), and micro fraction (less than ⅛”). The macro flakes were fully cataloged with all attributes recorded, whereas the meso flakes were cataloged collectively per experiment and stage with only their count and total weight recorded. Micro flakes were bagged separately and not cataloged. Bergene and I proceeded to work through each experiment in this way. She collected data on experiments 1, 6, and 8, while I collected data on experiments 2, 3, 4, 5, 7, and 9 (Bergene, 2022).

As guided by aspects of Sullivan and Rozen (1985), Andrefsky (2007), Milne (2009), Shott (1994), and Hamline’s Archaeology Lab Lithic Waste Analysis Protocol (Hoffman & Seaberg-Wood, 2020), each attribute was measured and recorded in the following way:
**Reduction Stage:** Provided by Dan Wendt (2020).

**Reduction Type:** Provided by Dan Wendt (2020).

**Count:** Bifaces (or biface fragments), as well as frost spalls/fractures, received a count of 0 in our dataset. This was done to keep our dataset as straightforward as possible. Thus, only macro fraction and meso fraction flakes were included in the data analysis.

**Class:** Following Sullivan and Rozen (1985) and Hoffman and Seaberg-Wood (2020), flake class is composed of five categories: complete flake (WFC), broken flake (WFB), flake fragment (WFF), waste flake shatter-like (WLI), or waste shatter (WSH). Complete flakes have an intact striking platform and termination. Broken flakes have a present platform but absent termination, leading to flakes that are not representative of their original size. Flake fragments occur when dorsal and ventral surfaces can be identified, but there is no platform. Shatter consists of debitage that also lacks a platform, but it is not possible to identify ventral from dorsal. On the other hand, shatter-like consists of blocky flakes that are difficult to identify dorsal and ventral, but otherwise may not completely match shatter or fragment (B. Hoffman, personal communication, May 5, 2021).

**Raw Material:** Provided by Dan Wendt (2020).

**Cortex Percent:** Recorded as 0%, 1–50%, 51–99%, 100%, or platform only.

**Size Grade:** Utilized Hamline’s archaeology lab size grade sheet to record size grade to the nearest 0.5 centimeters.

**Length:** In millimeters, complete and broken flakes were measured from platform to termination, while flake fragments and shatter were recorded as maximum dimension.

**Width:** In millimeters, measured as 90° from the length.

**Thickness:** In millimeters, measured maximum thickness of each flake.

**Weight:** Recorded to the nearest 0.01 grams.

**Platform Grinding:** Recorded as absent, present, or not applicable.

**Lip:** Recorded as absent, present, or not applicable.

**Percussion Bulb:** Recorded as absent, diffuse, pronounced, or not applicable.
**Flake Termination:** Dependent on flake class. Recorded as feathered, sharp, stepped, hinged, plunged, flaw, cortical, bipolar, or indeterminate.

Once data collection was complete, Bergene and I went back and checked flakes with Professor Hoffman that we had questions about during our summer 2021 SCUR research. Much of our work that summer focused on Hamline’s lithic analysis protocol and attribute replicability. This led us to conduct attribute trials.

**Attribute Trials: Platform Angles and Dorsal Flake Scar Counts**

Reviewers of Hamline’s debitage analysis protocol brought attention to two attributes that must be addressed: platform angles and dorsal flake scars. In reviewing the literature and talking with colleagues, the recommendation was that dorsal flake scar counts be incorporated into Hamline’s protocol. While the measurement of platform angles is already a part of the protocol, it is still inconclusive as to whether it is more effective to measure the interior or exterior angle of the platform, or to measure both. This was the focus of my and Bergene’s SCUR 2021 research, where she examined dorsal flake scars and I investigated platform angles (Bergene, 2022).

The problem with platform angles is that different researchers have employed different ways of recording this attribute. Some researchers record interior angles, others exterior angles, and some record both. We do not yet understand the implications of this difference in methodology. A related problem is that consistent recording of platform angles has proven difficult in my own research, raising the question as to whether this data can be recorded in a reliable manner. Even among the literature, it seems that, overall, one prominent consensus is that the reliability and consistency of measuring platform angles are debatable (Andrefsky, 2005; Dibble & Rezek, 2009; Raab et al., 1979; Shott, 1994).

In reviewing methods and approaches, there is generally no specific explanation of techniques for measuring platform angles. Each article reviewed utilized exterior platform angles. However, there was no justification as to why interior angles (or both angles) were not measured. Though, numerous articles did note that the interior platform angle does not relate to the angle of blow (Dibble & Whittaker, 1981; Whittaker, 1994).

Many articles discussed the ways in which the exterior platform angle relates to flake morphology. Flake weight increases relative to platform depth as the exterior angle increases (Dibble & Rezek, 2009). The exterior angle is important for determining flake size. For instance,
as lithic reduction continues, angles become more acute while flake length decreases (Raab et al., 1979; Shott, 1994; Whittaker, 1994). Speth (1981) expands on this by claiming that a decrease in the exterior platform angle equals a decrease in flake length. This suggests that the larger the platform angle, the greater the accuracy required to remove the flake. Finally, Shott et al. (2000) claim that exterior platform angle and flake mass have a weak correlation.

To test the reliability of platform angle measurement across analysts (myself, Bergene, Forest Seaberg-Wood, and Professor Brian Hoffman), twenty flakes with platforms were chosen from Wendt experiments six (Exp.20.6) and nine (Exp.20.9). Exp.20.6 was knapped with Oneota Chert, whereas Exp.20.9 was knapped with Knife River Flint. (Again, we must acknowledge the role of raw material.) After much discussion, we decided that to measure the platforms, we would hold the edge of the protractor against the platform of the flake while taking the measurement based on the midline of the flake termination. The angle taken was dependent on whether we were measuring the interior or exterior angle, and were measured to the nearest five degrees (see Fig. 4).

![Figure 4: Measuring platform angles (Photo by E. Larson).](image)

After making some adjustments to the flake sample, Bergene, Seaberg-Wood, Professor Hoffman, and I each measured the exterior platform angles of the Exp.20.6 flakes. Using Professor Hoffman’s measurements as a baseline, we then compared the rest of our measurements to his. The process was repeated for Exp.20.9, before replicating it for both
experiments and interior platform angle. However, when measuring the interior platform angle of Exp.20.6, we marked the platforms of each flake to ensure consistency between where on each flake we were taking our measurements from—as the breakage of Oneota Chert can make it difficult to locate the platform consistently.

From these trials, we have determined that the interior platform angle is more reliably measured across analysts. It is also clear that the raw material utilized plays a role in the ability to measure platform angles. For instance, the Oneota Chert platforms were much more difficult to recognize and measure consistently between the four of us. This called for marking the platforms on the Exp.20.6 flakes to make sure we all were measuring the same location. However, because Exp.20.9 flakes were knapped with Knife River Flint, the platforms were much clearer and did not require marking.

Additionally, at the beginning of the attribute trials, we noted many issues that needed to be addressed in order to move forward with our study. We had to grapple with errors from flakes that had platform crushing, as well as those that had particularly lumpy, cortical platforms. However, measuring the interior platform angle and confirming where the platform was between us seemed to significantly reduce these errors.

In sum, while the other attributes in Hamline’s protocol are easily replicated, our analysis shows that there are still areas of platform angles and dorsal flake scar counts that need to be addressed before a decision to implement them can be made.

**Process and Limitations**

Through the process of data collection and the attribute trials, I recognize the subjectivity associated with the measurement of the flake attributes. While size characteristics (i.e., size grade, length, width, thickness, weight) are more objective, the other features require more lithic training in order to properly interpret the debitage. Bergene and I first learned basic lithic analysis during Professor Hoffman’s fall 2019 Lab Techniques in Archaeology course. We then spent SCUR 2020 taking the time to undergo in-depth retraining on the analysis of lithic attributes.

The lithic training was based on the literature as well as the guidance of Professor Hoffman and Seaberg-Wood. The reason for this preparation was to get everyone on the same page with measurement methods. It is one thing to read about how other lithic analysts examine these attributes, but it is entirely different to actually have the flakes in hand and try to measure them. I
hope this research sheds light on the importance of considering subjectivity and error among the data, as well as the further implications this may have on archaeological interpretations.

**Results**

*Expectations and Hypotheses*

Based on the plethora of literature supporting this research, there are expectations and hypotheses for what the different attributes should portray for the different reduction strategies. For instance, because flintknapping in itself is a reductive technology, flakes should generally get smaller, thinner, and lighter in weight as one gets further into the knapping process. This would make early stage biface debitage larger and more cortical than late stage biface debitage (Andrefsky, 2005; Callahan, 1979; Shott, 1994). The size and shape of the starting cobble are variables that can also influence debitage attributes, particularly cortex percentages (Bradbury & Carr, 1995).

Additionally, I expect that raw material and percussor will play a significant role in the way the flake attributes are displayed within these experiments. These two elements have the potential to make it more difficult to establish distinguishing factors between reduction strategies. Expectations for other attributes are less clear; thus, the experiments contribute to further understanding of their relationship to reduction strategies.

*Summary of the Data*

When accounting for the macro fraction and meso fraction, a total of 4,215 flakes contributed to the dataset. Of those, 1,303 were fully cataloged and analyzed for the above attributes (the macro fraction, see Fig. 5). For the purposes of examining the data, the remainder of this thesis will focus solely on the macro fraction, although future researchers may find it useful to explore the meso and micro debitage datasets from these experiments.
Looking at the number of flakes per experiment, Figure 6 shows that experiments one (Exp.20.1) and six (Exp.20.6) have notably larger flake counts compared to the rest. There are a number of factors that could be causing these experiments to have such significant debitage counts. First, both experiments were generated using Oneota Chert, a low-quality material prone to greater shattering than GMC or KRF. Further, at least for experiment one (Exp 20.1), it could have to do with the size of the initial core and the success in producing a finished stage 3 thinned biface. However, the same cannot be said for experiment six (Exp.20.6), from which Wendt (2020) was unable to make a stage 2 biface. These spikes in flake count are an anomaly that will require further study.

Figure 5: Flake count for macro fraction vs. meso fraction for all nine Wendt experiments combined. Results will focus on the macro fraction.
Considering raw material, as demonstrated above, a majority of the debitage analyzed consisted of Oneota Chert, followed by Knife River Flint, with Grand Meadow Chert making up the smallest dataset (see Fig. 7).

*Figure 6: Flake counts per experiment. The chart is further divided by raw material, with gray representing Oneota, red for GMC, and tan for KRF.*

Flakes Per Experiment

*Figure 7: Number of macro fraction flakes per raw material.*
Raw Material. I first examine whether or to what extent raw material impacts the data. As an analyst, I noted that the attributes were more recognizable in higher quality material, making these features much easier to examine and measure. I expected that the differences in raw material quality between KRF, GMC, and Oneota Chert would show up in the attributes of their debitage. As demonstrated in Table 2, higher quality material such as KRF produces thinner, more complete flakes. On the other hand, lower quality material like Oneota creates thicker flakes that are more shattered, broken, and fragmentary (Bakken, 2011; Eren et al., 2014; Wendt, 2014). Importantly, though, the relationships between debitage attributes and reduction strategy exhibit similar patterns for all three raw materials. So, although I recognize that the raw material does influence my results, I decided to include all three raw materials in my thesis analyses. Future studies could include larger samples of different raw materials to explore this factor.

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Flake Class</th>
<th>Average Thickness</th>
<th>Flake Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMC</td>
<td>Broken</td>
<td>2.82</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Complete</td>
<td>3.91</td>
<td>79</td>
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<tr>
<td></td>
<td>Fragment</td>
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<td>GMC Total</td>
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<td>3.28</td>
<td>168</td>
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<tr>
<td>KRF</td>
<td>Broken</td>
<td>2.52</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Complete</td>
<td>3.12</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>Fragment</td>
<td>1.87</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Shatter</td>
<td>3.75</td>
<td>2</td>
</tr>
<tr>
<td>KRF Total</td>
<td></td>
<td>2.70</td>
<td>193</td>
</tr>
<tr>
<td>Oneota Chert</td>
<td>Broken</td>
<td>4.30</td>
<td>289</td>
</tr>
<tr>
<td></td>
<td>Complete</td>
<td>4.46</td>
<td>237</td>
</tr>
<tr>
<td></td>
<td>Fragment</td>
<td>3.40</td>
<td>373</td>
</tr>
<tr>
<td></td>
<td>Shatter-like</td>
<td>17.67</td>
<td>4</td>
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<tr>
<td></td>
<td>Shatter</td>
<td>8.85</td>
<td>39</td>
</tr>
<tr>
<td>Oneota Chert Total</td>
<td></td>
<td>4.23</td>
<td>942</td>
</tr>
<tr>
<td>Grand Total</td>
<td></td>
<td>3.88</td>
<td>1303</td>
</tr>
</tbody>
</table>

Table 2: Raw material by flake class and average thickness. Note that higher quality material (KRF) produces thinner flakes than lower quality material (Oneota).
**Percussor.** Similar to raw material, I found it important to gain an initial understanding of the impact of the flintknapping percussor on the attribute data. As shown in Table 1, Wendt primarily used a moose antler (soft percussor) but did use a hammerstone (hard hammer) for experiment seven (Exp.20.7), as well as a variety of percussors for experiment two (Exp.20.2). So, does percussor make a difference? This can be answered by simply examining reduction type and flake thickness.

These overall results show that hard hammer biface (Exp.20.7) produces much thicker flakes, on average. Because of this outlier, hard hammer biface will be removed from the examination of bifacial reduction from here on out. Further, singling out experiment two (Exp.20.2), which used a variety of percussors, shows that this tool method creates another outlier that will be removed (see Table 3). The remaining experiments (1, 3–6, 8, and 9) put the total dataset at 1,085 flakes. Future analysis will need to be done on the effects of percussor type.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Percussor</th>
<th>Average Thickness</th>
<th>Flake Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biface</td>
<td>Moose Antler</td>
<td>3.09</td>
<td>562</td>
</tr>
<tr>
<td>Core/flake</td>
<td>Moose Antler</td>
<td>3.91</td>
<td>523</td>
</tr>
<tr>
<td>Exp.20.2</td>
<td>Various</td>
<td>5.09</td>
<td>113</td>
</tr>
<tr>
<td>Exp.20.7</td>
<td>Hammerstone</td>
<td>6.7</td>
<td>105</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>Hammerstone</strong></td>
<td><strong>3.89</strong></td>
<td><strong>1303</strong></td>
</tr>
</tbody>
</table>

*Table 3: Percussor by reduction type and average thickness. Experiments 20.2 and 20.7 have been separated to show the outliers in flake size produced by different percussors.*

**Flake Class.** As displayed in Figures 8–10, there are notable differences in the results of flake class among the different reduction types. Biface reduction (both early and late) consists primarily of complete flakes. However, the late stage is similar to core/flake in that shatter is present. On the other hand, while core/flake has greater amounts of shatter, it consists mostly of flake fragments.
These results are consistent with Sullivan and Rozen’s (1985) correlation between higher amounts of shatter and core/flake reduction. Additionally, these results are further supported considering most core/flake experiments were generated with low-quality Oneota Chert.

Figure 8: Flake class among early stage biface reduction.

Figure 9: Flake class among late stage biface reduction.

Figure 10: Flake class among core/flake reduction.
**Cortex Percentage.** When assessing dorsal cortex percentage, there are dramatic differences between reduction types (see Fig. 11). As predicted, early stage biface reduction consists of greater amounts of dorsal cortex than late stage biface reduction. Coreflake reduction follows a similar pattern to late stage biface, where the amount of dorsal cortex becomes gradually smaller. However, generally, biface (complete) reduction and coreflake reduction follow similar progressions leading to less and less dorsal cortex (see Fig. 12).

![Dorsal Cortex Percentage by Reduction](image)

**Figure 11:** Dorsal cortex percentage by reduction type.

![Dorsal Cortex Percentage by Reduction](image)

**Figure 12:** Dorsal cortex percentage by reduction type (biface complete).
**Size Characteristics.** Attributes regarding flake morphology followed the above expectations and hypotheses. As predicted, because flintknapping is a reductive process, early stage biface debitage remains larger than late stage biface debitage. Interestingly, average core/flake debitage measurements fall between the early and late stages of bifacial reduction in all size attributes (see Table 4). However, there does not seem to be a drastic difference between biface and core/flake reduction. On average, the latter just has slightly larger, heavier flakes.

<table>
<thead>
<tr>
<th>Reduction Type</th>
<th>Reduction Stage</th>
<th>Average Size Grade</th>
<th>Average Length</th>
<th>Average Width</th>
<th>Average Thickness</th>
<th>Average Weight</th>
<th>Flake Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biface</td>
<td>Early</td>
<td>2.91</td>
<td>23.25</td>
<td>19.43</td>
<td>4.32</td>
<td>3.60</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td>Late</td>
<td>2.14</td>
<td>15.82</td>
<td>13.74</td>
<td>2.71</td>
<td>0.85</td>
<td>431</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2.32</td>
<td>17.55</td>
<td>15.06</td>
<td>3.09</td>
<td>1.49</td>
<td>562</td>
</tr>
<tr>
<td>Core/flake</td>
<td>Total</td>
<td>2.39</td>
<td>19.30</td>
<td>15.75</td>
<td>3.91</td>
<td>2.59</td>
<td>523</td>
</tr>
<tr>
<td>Grand Total</td>
<td></td>
<td>2.35</td>
<td>18.39</td>
<td>15.39</td>
<td>3.48</td>
<td>2.02</td>
<td>1085</td>
</tr>
</tbody>
</table>

*Table 4: Size characteristics by reduction type.*

**Additional Attributes: Grinding, Lip, Bulb, and Termination.** In addition to flake class, cortex, and size attributes, Bergene and I also recorded features specific to the platform (grinding, lip, bulb), as well as flake termination. Flakes that lacked a platform (such as flake fragments or shatter) were scored as ‘Not Applicable’ for grinding, lip, and bulb attributes. As shown above, in Figures 8–10, it is thus no surprise that core/flake reduction has the highest ‘Not Applicable’ values across all platform attributes. This is also consistent with the primary flake termination for core/flake being stepped, as this category lacks a platform. For both biface and core/flake reduction, percussion bulb is the most present platform attribute, and stepped, sharp, and feathered terminations are the most prevalent. The entire results of these attributes are presented in the Appendix (see Figs. 13–16).
Discussion

In this thesis, I have examined how (or whether) it is possible to distinguish between core/flake and biface reduction—and, further, between early and late stage biface reduction—through lithic debitage analysis of nine experimental flintknapping assemblages. In order to do so, over 1,000 lithic waste flakes were studied and fully cataloged for the following attributes: flake class, raw material, dorsal cortex percent, various size and platform characteristics, as well as flake termination. Wendt (2020) provided initial experimental data and documentation that allowed Bergene (2022) and me to know what the reduction strategy of each lithic experiment was. Thus, the recording of attributes allowed for the survey of distinguishable patterns between reduction technologies.

The results have successfully provided some solid answers. Flake attributes do pattern with reduction strategies, particularly for flake class, cortex percentage, and flake size. As a measure of completeness, flake class does have analytic value. Late stage biface reduction has the highest percentage of complete flakes and the lowest percentage of flake fragments. Core/flake, in comparison, has the highest percentage of flake fragments and shattering.

Late stage biface reduction also jumps out in that it contains very little dorsal cortex. Interestingly, late stage biface and core/flake reduction both show similar progressions in the number of flakes with dorsal cortex. For these reduction strategies, the most frequent category was flakes with no dorsal cortex. The frequency of flakes in these assemblages continues to drop as the amount of dorsal cortex increases. Early stage biface reduction does not follow the pattern of progressively fewer flakes as cortex percentage increases. Most early stage flakes instead fall within the 1–50% cortical range. Further study of this anomaly should be conducted with a larger sample size, as well as with attention to the impact of raw material.

The size characteristics for all reduction methods were consistent across all attributes. As predicted and proved by archaeologists and lithic analysts, late stage biface debitage was smaller, thinner, and lighter when compared to both early stage biface and core/flake debitage. This research, therefore, provides greater support for expectations regarding flintknapping as a reductive process.

In sum, all attributes show various consistent patterns by reduction stage and type, with the most dramatic differences between late stage biface reduction and core/flake reduction. In applying these results to an archaeological assemblage, one could expect early stage biface
debitage to be generally larger and more cortical than late stage biface. Further, biface reduction would consist of more complete flakes than coreflake debitage, which includes more flake fragments and shatter.

While the results of this thesis are promising, there are many opportunities for future study. For instance, the effects of raw material and percussor should be further explored, as they play an important role in the display and interpretation of flake attributes. There is more to be learned from examining isolated raw materials, as well as studying more debitage generated from a hard hammer percussor. Additionally, it may be useful to create a dataset that includes more flintknapping methods, such as bifacial core reduction. The complexities of the overlap between biface and coreflake strategies could not be fully understood here due to the limitations of this thesis. Finally, more attention should be given to both inter-and intraobserver errors in relation to attribute measurement. There are a number of anomalies and factors to be addressed before definitive distinctions can be made between these flintknapping strategies.

**Conclusion**

Those who do not study lithics may mistakenly view stone tool production as a simple process. However, whether performed by ancient populations or modern flintknappers, these technologies are various and complex. While the stone tools created can provide clues as to how past peoples made a living and where they traveled, the debitage shows how they spent their time. No matter what reduction strategy was employed, each strike of the core held intention. This study has been invaluable in examining the choices flintknappers make and their correlation to generated material culture. As the adage goes, one person’s trash is another’s treasure, and it is up to archaeologists and lithic analysts to make these connections and help fill in the gaps in history.

Humans have been making stone tools for millions of years, and because lithics preserve so well, debitage may be the only connection left to the past. The results of this study lend themselves to future comparison against debitage from archaeological pre-contact sites across Minnesota to understand stone tool production and the lives of those who came before us. I only hope that my portion of this research spurs further collaboration and study to learn more about the human story.
Acknowledgments

I am beyond grateful to have had the opportunity to partake in this research project with so many great collaborators. Not only have I learned a significant amount about lithics along the way, but the past three years have given me a greater appreciation for the process of research itself. For this, there are many people to thank:

First and foremost, I would not have gotten involved in this project without the initial enthusiasm of Delaney Grundhauser (2021). Her insistence that I could conduct archaeological research was convincing enough for me to pursue it. Additionally, the previous research conducted by Avery Marshall (2019) provided methods and insights that have given Hannah and me a foundation to stand on.

My research could not have happened without Dan Wendt’s contribution of the lithic experiments. He has provided us not only with the experiments but also knowledge of flintknapping and raw material use. We are thankful for his support in answering all of our questions with the enthusiasm only someone so passionate about lithics could provide.

As for my cohort (who I can’t thank enough), I would next like to thank Hannah Bergene for sticking through the research process with me. There is no one else I would have wanted to look at rocks for eight hours a day with! It has been a privilege to grow in the discipline alongside her. A huge thanks goes to Forest Seaberg-Wood for all of her support, patience, and putting up with our antics in the lab over the last three years. Finally, none of this would have been possible without Professor Brian Hoffman. I have truly never met someone so enthralled by what they do. Both in and out of the classroom, his guidance, support, opportunities, and encouragement have allowed me to grow in and appreciate archaeology all the more. I would lastly like to thank my friends and family who have graciously listened to me ramble about rocks. Their unconditional love and support throughout this process have meant everything to me.
References


Appendix

Platform Grinding by Reduction

Figure 13: Platform grinding by reduction type.

Platform Lip by Reduction

Figure 14: Platform lip by reduction type.
Figure 15: Percussion bulb by reduction type.

Figure 16: Flake termination by reduction type.