Assessment of Lithic Reduction Methods

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Assessment of Lithic Reduction Methods

Hannah Bergene

An Honors Thesis
Submitted for partial fulfillment of the requirements
for graduation with honors in Anthropology
from Hamline University

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Abstract

The way lithic artifacts are analyzed is critical to understand human behavior. How lithic attributes are measured can add important context to archaeological sites and experimental lithic collections. By re-evaluating the way we analyze lithic reduction strategies and measure lithic attributes, we can come to a conclusion as to how they compare. In the project that will be described, nine lithic experiments created by expert flintknapper, Dan Wendt, will be measured and analyzed in accordance with the Hamline University Archaeology Lab Debitage Analysis Protocol. Assessing the data collected from these nine experimental collections allowed me and my fellow researcher, Eva Larson (2022), to answer important questions related to middle-range theory, the technical significance that certain attribute measurements bring, and potentially to be able to locate diagnostic differences between lithic reduction strategies used, based on the data collected.
Introduction

This thesis uses data collected from nine experimental flintknapped collections to analyze and compare lithic reduction strategies, and to analyze the accuracy of certain attributes. The way lithic (stone) tools and waste are analyzed and interpreted is critical to understand past human behavior. How we measure and analyze lithic data can tell archaeologists, flintknappers, and other researchers how stone tools were created and possibly help us understand how past populations utilized raw materials.

Working collaboratively with my co-researcher, Eva Larson, we cataloged and measured a series of lithic attributes (Hoffman & Seaberg-Wood n.d.) from nine experimental collections created by expert flintknapper, Dan Wendt. For this project, Wendt flintknapped nine experiments, consisting of two Grand Meadow Chert (GMC) samples, two Knife River Flint (KRF) samples, and five samples of the Oneota variety of Prairie du Chien Chert (PDC). Using three types of lithic reduction methods – core/flake, early stage biface reduction, and late stage biface reduction – Wendt created the collection sample we used for our project. We measured twelve different lithic attributes for analysis, but questioned the validity of two notable attributes – platform angles and dorsal flake scar count – due to their questionable reproducibility.

Because we questioned the reproducibility of these attributes, Larson and I also conducted attribute trials assessing the accuracy of platform angle and dorsal flake scar count measurements. These trials were conducted by myself, Larson, our advisor, Professor Brian Hoffman, and our lab supervisor, Forest Seaberg-Wood. By completing these trials, Larson and I have built evidence explaining the issues of measuring these attributes so more accurate methods can be developed.

This research analyzes experimental collections to assess potential diagnostics of lithic reduction strategies by analyzing potential patterns in flake attribute measurement. We want to understand how lithic attributes are measured and how they can add important context to archaeological sites and experimental lithic collections. By analyzing the way we measure attributes and types of lithic reduction strategy, we can come to a conclusion about how lithic reduction strategies compare and how effective lithic attribute measurement is to overall analysis.
Background

Middle-Range Theory

The review and connection of key terms is important to understanding the context of this research. By defining foundational terms, the reasons and significance of this project can be better understood. Middle-range theory is the concept of linking human behavior and natural processes to physical remains in the archaeological record (Binford 1979), bridging analytical data collected from lithic debitage with behavioral patterns. A term often used in the study of archaeology, the study of artifacts to understand human culture, middle-range theory takes objects and connects them to human action. If this research can show how we can correctly interpret methods of lithic analysis, this information can be used to find out more about how lithic artifacts were created. Linking human behavior to how people created their stone tools may help us further understand their choices of materials and how they procured and traveled with raw materials.

Lithic Technology

To begin understanding human behavior from rock flakes, we also need to know the workings of flintknapping and rock tool-making. We also need to learn how data can be collected from lithics to determine patterns of behavior. After this, it can be explained how Larson and I analyzed and interpreted the experimental lithic collection data.

Flintknapping and Experimental Archaeology

One of the best examples of middle-range theory and lithic technology is flintknapping, which is the process of creating lithic tools by hand such as projectile points, endscrapers, knives, etc. Chipped stone tools that are created by this tool production method also account for the majority of the production of pre-contact stone tools in archaeological assemblages in North America (Marshall 2019). Chipped stone tools are produced by flintknappers, or people who use forceful strikes to reduce and shape lithic raw material into the desired tool or form (Whittaker 1994). One of the most common types of chipped stone tools are bifaces, which are any lithic material flaked alternatively on two sides or surfaces (Sutton & Arkush 1994). The debris removed is called flakes or debitage. It is considered the waste of patterned reduction in chipped stone technology (Shott 1994). The majority of this waste material is not valued as the desired
end product and is often discarded in the same space it was produced, leaving unbiased data for archaeologists to assess (Shott 1994). However, while flakes may be considered as waste material from flintknapping activity, there is a reduction method where flakes are the desired product. In core/flake lithic reduction, the goal is to create large flakes from the rock core that can then be transported and further worked into tools for later use instead of being discarded.

Another type of tool production from flintknapping is bifacial reduction. Material is detached from both sides or “faces” in opposing directions to shape a preform or refined biface (Whittaker 1994; Kelly 1988). Unlike core/flake reduction, bifacial lithic reduction is split into two stages, early stage biface and late stage biface. These indicate the flake’s progression during flintknapping. Similar to core/flake reduction, bifacial reduction is important in understanding how lithic raw materials move across landscapes in archaeological contexts; unworked raw material packages are often too large to carry and bifacial reduction is a method of making lithics more transportable (Kelly 1988).

Other than making raw materials more transportable, flintknapping also creates durable tools that are meant to last. Although gathering raw materials makes it so lithics are more available for transportation and trade, a lack of accessibility acts as a “precondition for bifaces as use-life tools” because of their durability (Kelly 1988). Kelly (1988) notes the work and energy investment that goes into biface production, meaning bifaces have a long life-use and are not likely to be discarded with expedient tools. Maintenance through re-sharpening the large amount of tool edge area on a biface makes it easy to preserve (Kelly 1988).

Flintknapping and chipped stone tool production were essential to the people that used lithic stone tools to survive. Native Americans depended on flintknapping to hunt, cook, fight, and to perform other daily tasks. The necessity of these objects is comparable to how we use tools to adapt to our environmental and cultural demands today (Bakken 2011). Because of their necessary use, flintknappers had to know where and how to gather the correct type of raw material for tool-making.

Flintknappers (both past and present) use a variety of lithic raw material based on the materials available through trade, travel, or local procurement, but tend to seek raw materials with homogenous crystalline structures (Whittaker 1994). Amorphous crystalline structures such as obsidian (as noted by Whittaker (1994)) are ideal for working because of their glass-like composition, but are more likely faulty in their durability compared to cryptocrystalline raw
materials such as chert. The least ideal raw materials to work are those with coarse and grainy structures (Whittaker 1994). These less than ideal raw materials include sandy oolitic chert such as the Oneota Formation of the Prairie du Chien Chert (PDC) group located in the Spring Coulee Complex in Wisconsin. However, because Prairie du Chien Chert ranges in quality, there is evidence of selective utilization of Prairie du Chien Chert at archaeological sites throughout the upper Mississippi River Valley, meaning some forms of this chert were preferred over others for tool-making (Wendt 2014).

In addition to considering the quality of raw material, the tools that are used to flintknap rock are important to note. The range of tools used by flintknappers include billets or rods of wood, antler, bone, ivory, horn, and hammerstones as precursors to strike raw material (Crabtree 1972). Many modern flintknappers, in addition to more historically accurate precursors (striking tools), also use blunt metal billets to create desired results. The nine experimental lithic collections that are analyzed in this project were primarily flintknapped using a moose antler billet (Wendt 2020) as the precursor. For each of the experiments, Wendt attempted to create bifaces to represent the finished product. He also kept the core that the flakes and final biface originated from. While the rock core and final biface are present in each experiment, they will not be incorporated in the data analysis (as will be explained later). The goal of this project is to analyze only the fully cataloged flakes from the process of Wendt’s flintknapping. From what we learn from analyzing the flakes from each of the experimental lithic collections, we can better understand how flintknapping impacts the creation of lithic tools.

The notion of creating, analyzing, and collecting data from modern flintknapping collections is a form of middle-range theory known as experimental archaeology (Bradbury & Carr 1995, 1999). By replicating methods that were suspected to be used in creating archaeological lithic collections, researchers can better interpret the process that went into the chore of creating stone tools. Variables such as the gathering and trading of raw material, how flintknapped tools were used, and even sometimes the length of time it may have taken to create lithic tools have to be considered when analyzing experimental collections.
Reduction Strategy

Flintknapping, by its definition, is a reductive strategy, in which the material over the time it is worked becomes smaller or lesser as the raw material is worked into the desired result. There are three different lithic reduction strategies that will be analyzed in this project: core/flake reduction, early stage bifacial reduction, and late stage bifacial reduction. Each method is slightly different, though all aim to create the same variety of lithic tools. Wendt used either the core/flake strategy or the early/late stage biface strategies to create the experimental collections that are in this project.

Core/Flake Strategy

Core/flake reduction is when cobbles of rock are worked into cores, which are then reduced into flakes. The usable flakes broken off from the core are then developed into bifacial tools. There are also ways in which the flintknapper can shape the core and strike raw material (rock) to produce particular types of flake shape, which assist the flintknapper in the later steps of tool-making. Blade cores are an example of this shaped core strategy.

As cores are being worked, flakes still have the most cortex (the outside layer of rock) on the platform and dorsal sides of the flake (see Figure 3). When conducting debitage analysis with core/flake reduction, one uncertainty is the predictability of the presence/absence and the amount of certain attributes such as cortex percentage (see Figure 4) of a flake. One of the aims of this research is to determine if there are any diagnostics for core/flake reduction in the analysis data of the experimental lithic collections.
Biface Strategy

Bifaces are defined as any lithic material flaked alternatively on two sides or surfaces (Sutton & Arkush 1994). Most modern flintknappers today use and distinguish biface strategies, which include two phases of reduction: early stage biface reduction and late stage biface reduction.

Early Biface

Early stage bifaces have sinuous edges (margins) and simple surface topography (Sutton & Arkush 1994). This first stage includes the edging and initial thinning of the biface as well as the decrease in the attributes that will be analyzed and measured in the later stages (Callahan 1979). Attributes such as dorsal cortex percentage, size, weight, etc. will tend to gradually decrease into the later stage of the process.

Late Biface

Late stage bifaces have straight edges and complex surface topography (Sutton & Arkush 1994). Late stage biface reduction follows the early stage, and includes the final thinning and shaping of the worked biface. Here, a smaller proportion of nearly every attribute from the resulting flake debitage (waste flakes) is present (Callahan 1979). As larger flakes are broken down and shaped as the biface becomes more finished, the flakes become smaller and the tool becomes more refined.

Figure 2: Early Stage Biface (a) & Late Stage Biface (b). Image provided by Sutton & Arkush (2002).
Debitage Analysis

Debitage analysis is a method used to gather information from the debris (flakes and shatter) produced by chipped stone tool production (Carr and Bradbury 2001). Lithic debitage has a specific anatomy as a result of reduction technology and the morphology of the material. By describing the anatomy of lithic flakes, it will be easier to interpret the process of attribute analysis and the data assessment from the experimental lithic collections.

Complete flakes have an intact striking platform at the proximal end where the material was hit to detach the flake from the core (Shott 1994; Sullivan and Rozen 1985). Great force is needed to detach a flake from the core, and evidence of this is in the bulb underneath the platform where this force is absorbed. The bulb is located on the ventral surface of the flake and is the “fresh” exposed surface that is created when the flake is detached from the core. At the distal end is called the termination of the flake. On the pre-existing backside of the flake, called the dorsal side, it is likely to find cortex or other indication of earlier-stage reduction such as flake scars caused by previous reduction flakes (refer to Figure 3).

Attributes for Analysis

The following attributes are essential to the analysis in understanding lithic reduction strategies. Larson and I analyzed each of the nine experimental lithic collections measuring all of the attributes listed below for each flake throughout the project. We measured each attribute


Flake Class
Flake class categorizes the completeness of flakes, following Sullivan and Rozen (1985). There are four categories: waste flake complete (WFC), waste flake broken (WFB), waste flake fragment (WFF), and shatter (WSH). WFC has an intact platform and termination on both the proximal and distal ends of the flake. WFB has an intact platform, but the termination of the flake has either broken off and/or is not representative of the original length and size of the flake. WFF have missing platforms but have identifiable ventral (front) and dorsal (back) surfaces. WSH have two ventral surfaces, which can be more commonly associated with bipolar reduction, but cannot be classified as a complete, broken, or a fragmentary flake (Hoffman & Seaberg-Wood n.d.; Shott 1994; Sullivan & Rozen 1985).

Raw Material
Raw material refers to the specific type of rock the flake is made of. Formal lithic raw material identifications are made using categories described by Bakken (2011, 2015) and Morrow (1994). For this project, identification of raw material was recorded by Dan Wendt (2020) during his formation of the nine lithic experiments. Raw material is a way to understand how the organization of technologies was present at an archaeological site because raw material informs lithic strategy as well as trade economy. Recording this attribute also helps researchers to interpret the availability of different raw materials within different archaeological contexts. The recording of raw material in this project, however, will inform us how Oneota Chert, Knife River Flint (KRF), and Grand Meadow Chert (GMC) can be worked using the three lithic reduction methods.

Cortex Percentage
Cortex percentage records the presence of the very outside layer of rock on a flake, and is an important part in understanding lithic reduction processes. There are five categories of cortex percentage according to the Hamline University Archaeology Lab Protocol: 0% (A), 1-50% (B), 51-99% (C), 100% (D), and platform only (E) (Hoffman & Seaberg-Wood n.d.). Dorsal cortex percentage is based on what is observed by the researcher. As a flake is worked into the desired
tool, the amount of cortex tends to decrease (refer to Figure 4) (Andrefsky 2001; Hoffman & Seaberg-Wood n.d.).

![Figure 4: Dorsal Cortex Percentage. Photo taken by Hannah Bergene, 2021.](image)

**Size Grade**

Size grade is one of the most accurate size measurements recorded during lithic analysis. The flake is placed on a sheet with a diagram of circles portraying different sizes of circumference, with each circle increasing every 0.5 cm. The flake is placed in the center of the diagram, and is measured by looking at the circle that most closely encompasses the flake by the nearest 0.5 cm. Because the size grade diagram increases in circumference every 0.5 cm, the size grade measurement is more consistently replicable when compared to the measurement of other attributes, because an exact measurement isn’t required (Hoffman & Seaberg-Wood n.d.). Figure 5 below shows an example of a flake with a size grade of 7.

![Figure 5: Size Grade. Photo taken by Hannah Bergene, 2021.](image)
Length
Flake length is recorded to the nearest hundredth millimeter (0.01 mm) using electronic calipers and is measured typically from the platform of the flake to the termination at the longest point. If the platform, termination, or both are absent, the debitage is measured at the longest point, with no consideration to where the platform or termination may have been. For example, flakes classified as WFC (complete) or WFB (broken) will be recorded measuring from the platform to the termination of the flake. Flakes classified as WFF (fragment) or WSH (shatter) will be recorded measuring the maximum dimension of the flake because of the absence of a platform. Length is inversely linked with the stages of reduction, so as a flake is worked into the desired tool, the length of the flake also tends to decrease (Hoffman & Seaberg-Wood n.d.).

Width
Flake width is recorded to the nearest hundredth millimeter (0.01 mm) using electronic calipers. Width is always measured perpendicular to the length of the flake, or 90 degrees from length measurement (Hoffman & Seaberg-Wood n.d.).

Thickness
Flake thickness is recorded to the nearest hundredth millimeter (0.01 mm) using electronic calipers. Thickness was measured at the thickest point on the flake and may be related to the type of precursor (tool) used (refer to Table 1 below). As a flake is worked into the desired tool, the thickness of the flake also tends to decrease (Hoffman & Seaberg-Wood n.d.).

Weight
The weight of each flake was recorded to the nearest hundredth gram (0.01 g) using an electronic scale. As a biface is worked into the desired tool, the weight of the flakes also tend to decrease (Hoffman & Seaberg-Wood n.d.).

Platform Grinding
The platform of a flake is located on the proximal end where the flake was initially struck. There are three categories for this attribute: present (P), absent (A), and not applicable (N). Because of the attribute’s location, only WFC (complete) and WFB (broken) flakes are able to have present or absent platform grinding. WFF (fragment) and WSH (shatter) flakes are always classified as not applicable (N) (Hoffman & Seaberg-Wood n.d.).
Lip

The flake lip is located on the ventral surface of the flake, in between the flake platform and flake bulb. There are three categories for this attribute: present (P), absent (A), and not applicable (N). Because of the attribute’s location, only WFC (complete) and WFB (broken) flakes are able to have a present or absent platform lip. WFF (fragment) and WSH (shatter) flakes are always classified as not applicable (N) (Hoffman & Seaberg-Wood n.d.).

Bulb

The bulb of percussion on a flake is located on the ventral surface, and occurs when the flake was struck off of the core by the flintknapper. There are three categories for this attribute: present (P), absent (A), and not applicable (N). Because of the attribute’s location, only WFC (complete) and WFB (broken) flakes are able to have a present or absent bulb. WFF (fragment) and WSH (shatter) flakes are usually classified as not applicable (N), though evidence of a bulb can still be present without the presence of the flake platform or lip (Hoffman & Seaberg-Wood n.d.).

Flake Termination

Flake termination is located on the distal end, opposite from the flake platform and records the termination of a flake using eight categories: feathered (FTH), sharp (SHP), stepped or broken (STP), hinged (HNG), cortical (COR), flaw (FLW), bipolar (BIP), and indeterminate (IND). Because of the attribute’s location, WFC (complete), WFB (broken), and WFF (fragment) flakes are able to record the flake termination. WSH (shatter) flakes are always classified as indeterminate (IND) or not applicable (N) (Hoffman & Seaberg-Wood n.d.).

Assessed & Discarded Attributes

The attributes Larson and I measured for debitage analysis (described above) were recorded because of their higher accuracy and predictability rate. Even though we analyzed most attributes involved with debitage analysis, two notable attributes were not included within our analysis: platform angle and dorsal scar count. Both attributes can be very useful when analyzing lithic reduction strategy, however, due to inter- and intra-observer variability, wide range of interpretation in literature, and measurement methods, it was decided that these two will not be recorded in our final debitage analysis.
Dorsal Scar Count

Scar count is measured by counting the individual scars located on the dorsal surface of the flake (Shott 1994). There are three stages for this assessment: stage 1 (1-2 scars), stage 2 (2-3 scars), and stage 3 (3 or more scars). This attribute hypothesizes that as the flakes become smaller, there will be an increase in flake scars due to the previous flintknapping activity before the current flake was broken off the core. The main contradiction with this attribute is that there is no consensus as to whether or not this is actually accurate. With this attribute, early stage flakes are often mistaken for late stage and vice versa, making the dorsal scar count measurement seem more randomized than previously thought (Bergene 2021).

![Figure 6: Dorsal Flake Scars. Photo taken by Hannah Bergene, 2021.](image)

Platform Angle

Platform angle is located at the angle where the striking platform and dorsal or ventral side meet, and is measured by taking a protractor and measuring the angle to the nearest 5 degrees (refer to Figure 7) (Shott 1994). This attribute can be measured recording either the external or internal platform angle of the flake, though most researchers default to the external platform angle. The interpretive use of platform angle determines the angle in which the flake was struck when it broke off the core. The hypothesis is that as the flakes become smaller, the (external) platform angle becomes larger, and vice versa for internal platform angles. However,
there is no consensus as to whether or not external platform angles or internal platform angles are more accurate, and there seems to be little accuracy on both sides of the argument (Larson 2021).

Attribute Trials

During the Student Collaborative Undergraduate Research Program of 2021, Larson (2021) and I decided to test the accuracy of these two attributes. To do this, we, along with our faculty advisor, Professor Brian Hoffman and lab supervisor, Forest Seaberg-Wood, conducted a set of experiment attribute trials to find out the potential accuracy of these attributes.

The trials themselves were represented by laying out a series of several flakes of randomized raw material, cortex, size, weight, and class on two separate trays. Each trial, arranged by Professor Hoffman, had twenty-five flakes, with one tray representing the trial test for platform angles while the other tray represented the trial test for dorsal scar count.

Before beginning our attribute measurements for each trial, Professor Hoffman and Seaberg-Wood measured their own assessments of the two attributes in question, acting as the correct measurements for each attribute for Larson and I to compare later. After Hoffman and Seaberg-Wood completed measuring the two trays, Larson and I each measured the trials and entered them into a shared spreadsheet with the recorded data from the four of us. The results of the compiled attribute measurements were then compared to each other.
In the assessment of platform angles, there were issues found with both inter- and intra-observer reliability. After the assessment of dorsal flake scar count, there were issues surrounding parameters of measurements, especially with the presence of retouched edges (small scars along the edges of a flake or biface).

Along with the attribute trials, Larson and I completed literature reviews based on what has been written about each attribute. Larson (2021) focused on the platform angle literature review while I wrote the dorsal scar count literature review. The write-ups of the attributes were completed in early fall, 2021, at the end of the Student Collaborative Undergraduate Research Program. Larson (2021) discovered that there were vague differences in measuring either exterior or interior platform angles. Most of the literature involving platform angles seemed to lean toward the exterior platform angle measurement, though there is no explanation given. In the literature for dorsal scar count, I (Bergene 2021) found that most researchers, including Shott (1994), agree that dorsal flake scars should be counted not including the retouched edges.

After writing the literature reviews, we set up the attribute trials a second time with the same two trays of flakes, this time only measuring the exterior versus interior platform angles. The new hypothesis being, that the internal platform angle will be more accurate due to the smoother shape of the flake bulb, versus the dorsal side, which could have random dorsal scaring and cortex to obscure accurate measurement. After the second round of platform angle trials, however, issues within our comparative results remained the same: there were still issues with inter- and intra- observer error in platform angles.
Methods

Lithic Experimental Collections

As previously mentioned, this research was completed with the help of Dan Wendt, who created and provided the nine experimental lithic collections to Larson and me in September 2020. With the collections, Wendt (2020) also provided his notes and data, recording the raw material, material source location, reduction approach, and the tool used to create each collection. The notes also recorded the results of each collection, as well as the overall measurements of each biface stage, as shown in Table 1.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Material</th>
<th>Source</th>
<th>Starting Weight (g)</th>
<th>Approach</th>
<th>Stage</th>
<th>Tool</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Oneota</td>
<td>Spring Valley, W</td>
<td>839.1</td>
<td>Biface</td>
<td>Early &amp; Late Stage</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 Stage</td>
<td>Various</td>
</tr>
<tr>
<td>3</td>
<td>GMC</td>
<td>GM, MN</td>
<td>210.4</td>
<td>Biface</td>
<td>Early &amp; Late Stage</td>
<td>Moose Antler</td>
</tr>
<tr>
<td>4</td>
<td>GMC</td>
<td>GM, MN</td>
<td>189.6</td>
<td>Core/Flake</td>
<td></td>
<td>Moose Antler</td>
</tr>
<tr>
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<td>Oneota</td>
<td>Spring Valley, W</td>
<td>144.9</td>
<td>Core/Flake</td>
<td></td>
<td>Moose Antler</td>
</tr>
<tr>
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<td>Spring Valley, W</td>
<td>2030.0</td>
<td>Core/Flake</td>
<td></td>
<td>Moose Antler</td>
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<td>Early Stage</td>
<td>Hammerstone</td>
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<td>KRF</td>
<td>Halliday, ND</td>
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<td>Core/Flake</td>
<td></td>
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<tr>
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<td>KRF</td>
<td>Halliday, ND</td>
<td>198.9</td>
<td>Biface</td>
<td>Late Stage</td>
<td>Moose Antler</td>
</tr>
</tbody>
</table>

Table 1: Experiment Overview. Replication of notes provided by Wendt 2020.
*Indicates biface broke during experiment.

Referring to the table above, the experiments themselves consisted of three raw materials: Oneota Chert, Grand Meadow Chert (GMC), and Knife River Flint (KRF), and were made primarily using moose antler during the flintknapping process. Only two experiments used different tools (“various” for experiment 2 and hammerstone for experiment 7). Wendt also recorded that experiments 1, 2, 3, 7, and 9 were created using the biface reduction strategy and experiments 4, 5, 6, and 8 were created using the core/flake reduction strategy. The Oneota Chert was collected from Spring Valley, Wisconsin and Louisville, Minnesota; the Grand Meadow Chert (GMC) was collected from Grand Meadow, Minnesota; and the Knife River Flint (KRF) was collected from Halliday, North Dakota. The asterisks located in the Experiment column of Table 1 indicate that the biface had broken during the experiment.

When the experimental collections were brought to Larson and me in September 2020, each collection was contained in several plastic bags. Each experiment bag contained one to three more bags inside, separating early stage biface flakes (labeled Stage 1-2) with later stage...
 biface flakes (labeled Stage 2-3). The extremely small flakes that were collateral waste collected after the biface was flintknapped could not be separated by early or late biface stages, and were put into their own unlabeled bag.

For each experiment, Larson and I began by labeling and cataloging each rock core, finished biface, and early and late stage macro-flakes (greater than ¼ inch), which were labeled with permanent marker by Wendt in the order in which they were struck off the core during flintknapping. This stage of labeling and data collecting typically started with the early stage flakes and ended with the later stage flakes according to the permanent marker number Wendt provided, working our way from the large flakes to the smaller flakes. In our data collection, we recorded all the attributes (flake class, raw material, cortex percentage, size grade, length, width, thickness, weight, platform grind, lip, bulb, and flake termination). The attributes were first recorded on paper and then typed into a digital record for later analysis.

After the bags of larger flakes were labeled and cataloged, we took the unmarked bag of extremely small flakes and sifted them using a hand screen, separating smaller macro-flakes (greater than ¼ inch) that could also be labeled and cataloged. Each hand screen contains a quarter inch screen and an eighth inch screen below it. The flakes greater than a quarter inch were still considered macro-fraction, and were fully cataloged with the other macro-flakes. The flakes that fell through the quarter inch screen but were greater than the eighth inch screen were considered meso-fraction (greater than ⅛ inch), and the flakes that fell through both the quarter inch and the eighth inch screens were considered micro-fraction (less than ⅛ inch).

While the macro-fraction flakes were individually measured, labeled, and cataloged, the meso- and micro-fraction flakes were recorded differently. Only the count and collective weight of the meso-fraction flakes were recorded and were given one record number in the catalog. Only the weight of the micro-fraction flakes was recorded and written on the bag they would be contained in; they were not given a record number in the catalog.

Larson ended up labeling and cataloging experiments 2, 3, 4, 5, 7, and 9. I ended up labeling and cataloging experiments 1, 6, and 8. After the labeling and cataloging of each experiment was completed, we began the process of data analysis.
Results

Data Analysis: At First Glance

The tables and graphs shown below represent the cumulative data gathered from the nine experimental lithic collections. To be sure of the accuracy of our data, Larson and I only analyzed the macro-fraction flakes that were fully labeled and cataloged. From Wendt’s table shown earlier (see Table 1), we can create a foundational set of representations for the information we were given.

Based on Wendt’s (2021) notes, we can see that five experiments were made of Oneota Chert, two experiments out of Grand Meadow Chert (GMC), and two experiments out of Knife River Flint (KRF). The table and graph for this are shown below:

<table>
<thead>
<tr>
<th>Number of Experiments</th>
<th>Biface</th>
<th>Core/Flake</th>
<th>Raw Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3</td>
<td>2</td>
<td>Oneota Chert</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>Grand Meadow Chert</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>Knife River Flint</td>
</tr>
</tbody>
</table>

Table 2: Number of Experiments & Raw Material.

Another set of information we can glean from Table 1 is an assessment of the total count of flakes from each experiment. The table below (Table 3) shows the raw material, the starting weight of each raw material, the macro-fraction (greater than ¼ inch) flake count, and the total count of each experiment. With this information, we can start to see how the starting weight of

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each experiment can transition into the resulting amount of flakes. In the table below, the flakes with a higher starting weight tend to have a higher macro count as well as a higher total flake count. This information, however, can also be affected by the raw material being worked on, the precursor being used, and the type of lithic tool Wendt wanted to create.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Raw Material</th>
<th>Starting Weight (g)</th>
<th>Macro Count</th>
<th>Total Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp.20.1</td>
<td>Oneota Chert</td>
<td>839.1</td>
<td>331</td>
<td>1025</td>
</tr>
<tr>
<td>Exp.20.2</td>
<td>Oneota Chert</td>
<td>288.9</td>
<td>113</td>
<td>291</td>
</tr>
<tr>
<td>Exp.20.3</td>
<td>Grand Meadow Chert</td>
<td>210.4</td>
<td>99</td>
<td>351</td>
</tr>
<tr>
<td>Exp.20.4</td>
<td>Grand Meadow Chert</td>
<td>189.6</td>
<td>69</td>
<td>215</td>
</tr>
<tr>
<td>Exp.20.5</td>
<td>Oneota Chert</td>
<td>144.9</td>
<td>50</td>
<td>140</td>
</tr>
<tr>
<td>Exp.20.6</td>
<td>Oneota Chert</td>
<td>2030.0</td>
<td>344</td>
<td>1154</td>
</tr>
<tr>
<td>Exp.20.7</td>
<td>Oneota Chert</td>
<td>1191.8</td>
<td>105</td>
<td>282</td>
</tr>
<tr>
<td>Exp.20.8</td>
<td>Knife River Flint</td>
<td>209.9</td>
<td>61</td>
<td>195</td>
</tr>
<tr>
<td>Exp.20.9</td>
<td>Knife River Flint</td>
<td>198.9</td>
<td>132</td>
<td>562</td>
</tr>
</tbody>
</table>

Table 3: Flake Count & Experiment

While we did not include a full assessment of meso- or micro-fraction flakes in our data assessment, the count of meso-fraction (greater than $\frac{1}{8}$ inch) flakes still affects the overall count in each experiment. In the bar graph below (Graph 2), the total counts of each experiment are represented by splitting up the macro- and meso-fraction flakes, with macro-fraction in blue and meso-fraction in red. By looking at the graph, we can see that a majority of the total flake count in each experiment comes from the meso-fraction flake count.

Graph 2: Flake Count & Experiment.
The next bar graph shown below (Graph 3) represents the overall flake count of each experiment once again, this time showing the count as well as the raw material type for each experiment. The gray bars represent Oneota Chert, the red bars represent Knife River Flint (KRF), and the yellow bars represent Grand Meadow Chert (GMC).

Looking at the graph, we see that experiments 1 and 6 have a notably higher flake count. This could lead us to suspect that raw material can affect flake count, however, we also see that experiment 5 is also made of Oneota Chert, but has the lowest count out of all the experiments. We see the same with experiments 2 and 7, which are also made of Oneota Chert, and have low flake counts.

Because raw material type doesn’t seem to correlate with flake count, we could also assume that the starting weight for each experiment can correlate with flake count. However, while this may be a good explanation for experiment 5, which has both the lowest weight and count, as well as experiment 6, which has both the highest weight and flake count, it is nearly the exact opposite for experiment 7, which has the second highest weight (1191.8 grams) but only the sixth highest flake count (282 flakes). The same can be said for experiment 9, with the seventh highest weight (198.9 grams) but the third highest flake count (562 flakes). The graph below (Graph 4) shows the comparison of the starting weight of raw material versus the total flake count of each experiment.
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Starting Weight (g)</th>
<th>Total Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp.20.1</td>
<td>839.1</td>
<td>1025</td>
</tr>
<tr>
<td>Exp.20.2</td>
<td>288.9</td>
<td>291</td>
</tr>
<tr>
<td>Exp.20.3</td>
<td>210.4</td>
<td>351</td>
</tr>
<tr>
<td>Exp.20.4</td>
<td>189.6</td>
<td>215</td>
</tr>
<tr>
<td>Exp.20.5</td>
<td>144.9</td>
<td>140</td>
</tr>
<tr>
<td>Exp.20.6</td>
<td>2030.0</td>
<td>1154</td>
</tr>
<tr>
<td>Exp.20.7</td>
<td>1191.8</td>
<td>282</td>
</tr>
<tr>
<td>Exp.20.8</td>
<td>209.9</td>
<td>195</td>
</tr>
<tr>
<td>Exp.20.9</td>
<td>198.9</td>
<td>562</td>
</tr>
</tbody>
</table>

*Table 4: Starting Weight & Flake Count.*

In Graph 4, we can see again that Experiments 6 and 7 have noticeable differences between starting weight and flake count, while Experiments 2, 4, 5, and 8 have comparably close ranges of the two attributes. Because one of our goals in this project is to compare the types of lithic reduction strategy, we can set up the starting weight and total flake count data to reflect this. Graph 5 below shows the reduction strategy of experiments 1, 3, 4, 5, 6, 8, and 9 by flake count and starting weight. Experiments 2 and 7 were excluded from this assessment because of their differing precursors used from the other experiments (as will be further explained below).
From Graph 5, we see that the experiments using coreflake reduction (Experiments 4, 5, 6, and 8) are generally clustered into similar weight and count ranges with one outlier. The experiments using biface stage reduction (Experiments 1, 3, and 9) are generally more spread out, with two having similar weights, and all three differing in flake count.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Reduction Type</th>
<th>Starting Weight</th>
<th>Total Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp.20.1</td>
<td>Biface Complete</td>
<td>839.1</td>
<td>1025</td>
</tr>
<tr>
<td>Exp.20.3</td>
<td>Biface Complete</td>
<td>210.4</td>
<td>351</td>
</tr>
<tr>
<td>Exp.20.4</td>
<td>Core/Flake</td>
<td>189.6</td>
<td>215</td>
</tr>
<tr>
<td>Exp.20.5</td>
<td>Core/Flake</td>
<td>144.9</td>
<td>140</td>
</tr>
<tr>
<td>Exp.20.6</td>
<td>Core/Flake</td>
<td>2030</td>
<td>1154</td>
</tr>
<tr>
<td>Exp.20.8</td>
<td>Core/Flake</td>
<td>209.9</td>
<td>195</td>
</tr>
<tr>
<td>Exp.20.9</td>
<td>Biface Complete</td>
<td>198.9</td>
<td>562</td>
</tr>
</tbody>
</table>

*Table 5: Starting Weight & Flake Count by Reduction Type*

Data Analysis: In Depth

The following represents the more extensive analysis of the nine lithic experiments. Here, I analyze specific attribute measurements, correlations, and similarities from Wendt’s (2021) experiments. Before proceeding to the results, it is necessary to explain the way in which the experiments were analyzed.

Throughout the data analysis of the nine experiments, Larson and I only analyzed the fully cataloged macro-fraction flakes from each experiment. Because the goals of our project are
to examine reduction types by measuring lithic attributes, it is more useful to analyze fully cataloged macro-fraction flakes.

The core and finished lithic tool of each experiment were not included in the assessment of the data because they are not flakes. Meso- and micro-fraction flakes were also not analyzed any further than the meso-fraction count and weight (as described earlier). Other than this, the meso- and micro-fraction flakes don’t add any more useful information to our data set.

As for the experiments themselves, Larson and I decided we would exclude experiments 2 and 7 from our attribute analysis because the precursor used to create them differed from the majority of the lithic experiments. From Wendt’s (2021) table, experiment 2 was created using “various” precursors, and experiment 7 was created with a hammerstone. Because the precursor material for experiments 2 and 7 are outliers in their precursor methods, they were also excluded from our data set.

Now that the main parameters of our methods have been described, the following data analyzes the three reduction strategies by the attributes Larson and I measured during our data collection.

Analyzing the types of flake reduction by flake class, Larson and I found that complete flakes (WFC) were more frequent in the biface reduction strategies, while fragmented flakes (WFF) were the most frequent classification for core/flake reduction. There is also no presence of shatter (WSH) in early stage biface reduction, very slight presence of shatter in late stage biface reduction, and the highest percentage of shatter occurs in core/flake reduction. Broken flakes (WFB) seem very similar in all three reduction types. The three pie graphs (Graphs 6, 7, and 8) below represent this data.

Graph 6: Reduction Type by Flake Class. (Early Stage Biface Reduction)

Graph 7: Reduction Type by Flake Class. (Late Stage Biface Reduction)
When analyzing cortex percentage, we noticed that late stage reduction (red) and core/flake reduction (yellow) have a gradual progression in cortex presence from cortex percentage D (100%) to cortex percentage A (0%). As the raw material is worked, the outer layer of rock is flaked off fairly quickly and occurs less frequently, so an increasing majority of the flakes in each collection will have less than 100% cortex. While late stage reduction and core/flake cortex percentage have gradual progressions, however, early stage reduction seems to have a spike in cortex percentage B (1-50%).

Analyzing the average count of attributes relating to size and weight, there are noticeable patterns to be found when comparing them by types of reduction. Of all three reduction strategies, early stage biface reduction (Stage 1-2) appears to have the largest averages across all size attributes, while late stage biface reduction (Stage 2-3) appears to have the smallest averages.
across all size attributes. Comparing early stage to late stage bifacial reduction (Stage 1-2 to Stage 3-4), there are noticeable size differences from early stage to late stage, especially when comparing the average weight of early stage (3.60 g) to late stage (0.85 g). There are also larger differences in average length, width, and thickness, meaning that the late stage biface flakes in our data set were overall smaller and very light-weight compared to early stage biface flakes. The closest range of average sizing between early stage and late stage appears to be size grade, early stage having an average size grade of 2.91 cm and late stage having an average size grade of 2.14 cm (refer to Table 7 below).

Comparing the average size attributes of core/flake reduction with early stage and late stage reduction, it appears the average sizing data set for core/flake reduction sits in between the data sets for early stage and late stage reduction data for all the sizing attributes. When comparing the total biface reduction (Biface Complete Total) to core/flake reduction, however, the data sets appear very similar to one another, with average length and weight being the largest differences.

<table>
<thead>
<tr>
<th>Reduction Type</th>
<th>Reduction Stage</th>
<th>Average of SG</th>
<th>Average of Length</th>
<th>Average of Width</th>
<th>Average of Thickness</th>
<th>Average of Weight</th>
<th>Sum of Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biface complete</td>
<td>1-2</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>2-3</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>Biface complete Total</td>
<td></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></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 6: Reduction & Average Count of Size Grade, Length, Width, Thickness, and Weight

While I discussed the comparison of lithic reduction types using flake class, cortex percentage, and size and weight measurements, I will not be analyzing the platform grinding, flake lip, flake bulb, or termination. Because we are focused specifically on the comparison of lithic reduction types for our project, none of these four attributes impacted our results because they didn’t indicate a progression of flintknapping. While Larson and I did not include an assessment of these attributes, there are four graphs located in the Appendix (pg. 38-39) comparing the three lithic reduction types by platform grinding, flake lip, flake bulb, and termination.
Discussion

Findings & Discussion

Summarizing the gathered data, we found that flint-knapping with Oneota Chert seems to generate more flakes than Knife River Flint or Grand Meadow Chert. We can also see evidence that starting weight and raw material may correlate with flake count. There also seems to be evidence of correlation when comparing the starting weight and flake count of the experiments by reduction type (refer to Graph 5). Looking at flake class, I found that the percentage of shatter is most diagnostic of the lithic reduction types. Core/flake reduction has the largest percentage of shatter flakes compared to early stage biface reduction (which had no shatter), and late stage biface reduction (which had a slight percentage of shatter). When comparing reduction type to cortex percentage, there seems to be a gradual progression from 100% to 0% cortex in both core/flake and late stage biface reduction. In contrast to this gradual progression, early stage biface reduction spikes at 1-50% cortex.

Lastly, for the comparison of average size attributes, there is noticeable progression from early stage biface to late stage biface reduction, indicating flake size gets progressively smaller as the flint-knapper works from early to late stage biface production. Interestingly, the average size attributes for core/flake reduction falls between early stage and late stage biface reduction. However, when comparing the average flake size of biface reduction in total to the size of debitage from core/flake, the results are very similar. This similarity between the combined biface reduction flake sizes and core/flake debitage suggests these two reduction strategies will be difficult to identify based on size alone. The difference in average flake size between early and late stage biface production, however, does suggest flake size can be used to identify differences in biface reduction.

When analyzing these data, Larson and I had to keep in mind factors such as types of raw material worked, starting weight of each raw material, types of precursor used, and the desired tools Wendt aimed to create in his lithic experiments. What we saw in the results may have varied dependency on these factors, so it was critical to remember all possible variables when we conducted our analyses. Considering the number of variables we had to work around and remember, it became difficult sometimes to interpret information without becoming confused or thinking of another avenue of analysis. By eliminating the experiments with differing variables
(Experiments 2 and 7 because of their precursor type), we created a data set that was more accurate for us to compare lithic reduction strategies.

Further Questions & Research

While some useful information can be taken from this project, there is a lot of potential for further research in lithic reduction strategy analysis. Several aspects from this project can be altered or changed to look for different results or to resolve certain inconsistencies. For instance, the experiments could be fixed by using the same variables, including type of raw material, type of precursor to be used, and similar starting weight for each experiment. Another variable that can be fixed is the type of reduction strategy used. All the experiments could be made using the same lithic reduction strategy, or an equal amount of both biface reduction and coreflake reduction to obtain more accurate variation. By eliminating these inconsistencies, future lithic reduction strategy analysis can be more accurate and useful for archaeologists, flintknappers, and other researchers.

Significance

From our findings, Larson and I were able to gather comparative and accurate information about lithic reduction strategies. By conducting the project using the methods and describing the results shown, Larson (2022) and I have added an important data set to the study of lithic reduction analysis, as well as lithic attribute analysis. This thesis has successfully described and analyzed diagnostic evidence between early stage biface reduction, late stage biface reduction, and coreflake reduction strategies. This thesis also makes clear the importance of flake anatomy and attribute analysis. From my research, I hope I provided a foundational starting point to more extensive lithic reduction analysis for future students and researchers.
Conclusion

This research started as a joint Student Collaborative Undergraduate Research (SCUR) project between Larson and me back in the summer of 2020, expecting to learn more about lithic flake assessment and reduction strategy. Instead, due to the COVID-19 pandemic, other research goals, and wanting to find out where our research could lead, it expanded into a three-year research project. Because of this project, Larson and I have been able to contribute another useful set of information to help expand the study of lithic analysis.

This thesis is based on the lithic analysis of nine flintknapping experiments created by Dan Wendt in 2021, where we sought to analyze potential diagnostics of lithic reduction strategies by analyzing potential patterns in flake attribute measurement. A total of 4,215 flakes, analyzed and cataloged between Larson and I measuring specific attributes in hopes of comparing and gathering evidence of diagnostic differences between bifacial and core/flake lithic reduction strategies. Other than the initial analysis of thousands of flakes, an attribute trial experiment also contributed to our assessment in the way lithic attributes are measured.

The goal of this project has been to allow lithic analysis to become more cohesive, comprehensive, and reliable for future archaeologists, flintknappers, and other researchers. My findings act as a part of understanding the valuing and reduction sequence of lithic raw material. Understanding lithic technology in this way allows us not only to gain technical knowledge of lithic analysis but also to gain a window into the human behaviors and patterns that were necessary in the lithic tool-making process.
Acknowledgements

I am so grateful to be able to complete this research over the course of the last few years. To express my gratitude, I would like to take this opportunity to thank all those who have guided, supported, and helped me throughout this process. I feel privileged and humbled to have worked with these people and to have gained the experience I have throughout my research.

First, this project would not have been possible without the help of my Hamline advisor, Professor Brian Hoffman, who pushed me to always do my best, who reminded me to remember why my research is important, and to always ask questions. He has allowed me to grow in my knowledge of archaeology, and I have benefited greatly from being able to participate in his classes, archaeology lab, field schools, and research.

I would also like to thank Forest Seaberg-Wood, who oversaw much of the research process and supported Eva and me in our research. She has helped guide the process of research in the right direction and we absolutely couldn’t have done it without her advice and motivation. My thanks to Dan Wendt, who provided us with the lithic experiments and notes that were the foundation of our project. Also many thanks to Avery Marshall and Delaney Grundhauser, who first got me involved in lithic analysis research.

I would also like to give a special thanks to my co-researcher, Eva Larson, who achieved this project alongside me. We have motivated and supported each other throughout this process and I am glad that we were able to do something like this together.

I am so grateful to have been a part of this project. This research will hopefully contribute to future lithic analysis done in Minnesota. I also hope that my research will help others to understand more about the importance of lithic reduction strategy and the role of how lithic attributes are measured. Thank you to these people for the opportunity and experience that this research project has given me. I have gained invaluable experience in the world of academia and how to properly conduct research both independently and collaboratively. Not only have I accomplished something that I am proud of doing myself, I also achieved this project together with a friend with whom I am proud to share credit.

I lastly give my thanks to all of my family, friends, and advisors for their support and encouragement throughout these past few years. Thank you for listening to my frustrations and feelings I have expressed because of my project. I am so grateful for the limitless motivation and encouragement you have provided to help me make this happen!
References Cited


https://digitalcommons.hamline.edu/dhp/81/.


Appendix

Graph 10: Platform Grind by Reduction Type.

Graph 11: Flake Lip by Reduction Type.
Graph 12: Flake Bulb by Reduction Type.

Graph 13: Termination by Reduction Type.