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The Organization of Technology in the Pine Hills of Mississippi

Ronald W. Wise Jr.
University of Southern Mississippi

THE ORGANIZATION OF TECHNOLOGY

IN THE PINE HILLS OF MISSISSIPPI

by

Ronald Wise Jr.

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Approved:

____
Dr. Homer E. Jackson, Committee Chair
Professor, Anthropology and Sociology

____
Dr. Marie E. Danforth, Committee Member
Professor, Anthropology and Sociology

____
Dr. Philip Carr, Committee Member
Professor, Sociology, Anthropology, and Social Work
University of South Alabama

____
Dr. Karen S. Coats
Dean of the Graduate School

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ABSTRACT

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This thesis details the use of experimental flintknapping to better understand stone tool production and the organization of technology among Woodland period hunter-gatherers within the Pine Hills region of Mississippi. The Pine Hills region is characterized archaeologically by the presence of numerous sites consisting of flake scatters and little other material remains. Local tool stone resources consist of high grade chert in the form of small river cobbles, which restricts potential tool forms available to users.

Research for this project focused on the statistical analysis of debitage created during the experimental replication of stone tools using local chert cobbles. Special attention was given to attributes of flake debris in relation to the tool production continuum. The results of this analysis indicate that a suite of attributes exists which accurately predict the position of a flake along the production continuum. Additionally, the results show that these attributes differ from those identified by previous studies.

These attributes were used to reexamine three archaeological sites within the project area (22FO1515, 22FO1545, and 22FO1546). The reanalysis of two of these sites indicates that they served as residential locations within a mobile hunter-gatherer foraging system. Reanalysis of the third site was unable to determine site function due to

site disturbance and the recovery procedure employed. Consequently, the use of 3.2 mm screens is suggested as standard recovery procedure within the Pine Hills.

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Multiple individuals are responsible to the completion of this project. A debt of gratitude is owed to master flintknapper and archaeologist Andrew Bradbury, whose assistance in interpreting the statistical analysis was invaluable. I would also like to recognize Mississippi National Guard archaeologist Rita McCarty for her help in sourcing local stone tool resources. Finally, I would like to thank my friend and colleague Nic Glass for his help in conducting and recording the knapping experiments presented in this thesis. Their contributions were vital to this study, and I am very appreciative.

DEDICATION

This thesis is dedicated in memory of John W. Cottier, my teacher and mentor, who awoke in me a desire to learn and discover the past. I will forever appreciate the time I spent with you, and I hope to pass along your spirit for learning just as it was passed to me.

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CHAPTER I - INTRODUCTION

This thesis examines the utility of experimental replication in understanding prehistoric archaeological debitage assemblages in the Pine Hills region of southeast Mississippi. Debitage analysis, at one time thought superfluous, has been shown to be of great importance in the documentation of settlement adaptations and organizational strategies of stone tool-reliant populations. The use of experimental replication has been widely recognized by lithic specialists as an informative way of accurately interpreting aboriginal data. Here, experimental data is presented, analyzed, and employed to create a method for interpretation of archaeological data. This method is then used to reconstruct the technological organization of three prehistoric sites: 22FO1515, 22FO1545, and 22FO1546. The reconstruction of lithic technological organization for these three sites adds to the documented knowledge of local settlement organization and increases the accuracy with which archaeological sites can be interpreted.

Background of Research Interest

The field of lithic analysis has, within the past few decades, undergone significant changes in both methodology and theoretical perspectives. Analytical methods have developed so that questions regarding a wide range of subjects can now be answered. However, as has been demonstrated (Carr et al. 2012; Price 2012), it seems that such analysis is susceptible to the possibility that alternative conclusions go unnoticed due to an apparent “stagnation of lithic analysis” with regard to the methodologies used in the southeastern U.S. (Carr et al. 2012:1). Despite this, multiple avenues of inquiry have been explored that shed light on the relationships between raw material availability, production strategies, and tool form. More specifically, the past two decades have witnessed the avenue of debitage analysis being re-examined such that there now exists multiple approaches that, when used together, contribute to a more holistic data interpretation. Using multiple lines of analysis allows lithic analysts to understand a wide range of past behaviors related to environmental adaptation, seasonal mobility, and resource exploitation, among others.

It has been well documented that the production sequences of various tool types are discriminant and that their recognition in the archaeological record is possible (Ahler 1989; Bradbury and Carr 1999; Magne 1985). However, the field of debitage analysis is still a contested methodological space (Andrefsky 2005:113), and this project is aimed at further testing and refining these methods. Using an organization of technology approach and multiple analytical methods, inferences regarding tool form and reduction strategy are obtained here, producing a greater understanding of past human adaptation in both an environmental and social context. Integral to these methods is experimental replication, which allows for the controlled measurement of environmental factors that influence lithic material form.

For the Pine Hills of southeast Mississippi, evidence for the manufacture and maintenance of stone tools is often the only signature of past site activities. It was once believed that this area of the state lacked meaningful archaeological data, but increases in fieldwork and research interest have demonstrated that archaeological material is, in fact, widely distributed (Jackson et al. 2002). Because advances in lithic debitage analysis have brought an increase in the interpretive power of local sites, the ability of researchers to accurately understand lithic material is key to understanding prehistoric ways of life.

The present research focuses on how flintknapping experimentation might lend insight to the analysis of three prehistoric sites—22FO1515, 22FO1545, and 22FO1546—located within the Pine Hills physiographic region of southeastern Mississippi. Radiocarbon dating suggests that two of the sites, 22FO1515 and 22FO1546, were inhabited during the Late Woodland period, which is supported by the respective artifact assemblages. Moreover, the suggested ranges of dates overlap, meaning both could have been inhabited at the same time or inhabited sequentially over the course of multiple residential moves or relocation events. The excavation of each site produced variable amounts of lithic debris, the analysis of which is capable of producing an understanding of the reduction strategies employed at each locale, and in turn, differences regarding other aspects of behavior.

Of note is the relative utility of each site under examination in this project. All three sites lie on upland ridges overlooking Davis Creek within the Camp Shelby Joint Forces Training Center in Forrest County, Mississippi. The two larger sites, 22FO1515 and 22FO1546, were shovel tested and then selectively excavated using 3.2 mm screens according to artifact densities. Consequently, the respective assemblages appear more representative of the activities that occurred there in the past. Because of the overwhelming abundance of recovered material at 22FO1515, a sample of 26.9 percent (n=3873) of the curated material was analyzed for comparison. In contrast, the analysis for 22FO1546 was accomplished in total (n=1074). The third site, 22FO1545, was found during testing to be highly disturbed as a result of modern logging events and that this had left several baked clay features exposed. Accordingly, these features were stripped with the aid of heavy machinery in clearing overburden which produced a much smaller lithic assemblage (n=101). The difference in assemblage size at 22FO1545 was a product of both modern cultural disturbances and considerations of time and budget. Thus, the inclusion of this site will yield better knowledge of the ability of surface collections to accurately reflect prehistoric cultural activity. This is only possible if one makes the assumption that this site was formed in a similar manner as the other two. Because it produced similar cultural materials, this assumption is at the very least not without support. Therefore, it serves as a useful example of the differences in explanatory power between the recovery methods.

In terms of function, Jackson (2012) concluded that 22FO1515 was likely a residential site. This was based on the large amount and wide variety of lithic materials recovered and the presence of low-fired baked clay, thought to be a product of earth ovens or hearths. Aside from the recovery of substantial amounts of lithic debitage (n=14,385), nine formalized or exhausted bifaces, five projectile point/knife fragments, one retouched microblade, and twenty-three unfinished or abandoned bifaces were collected. Seventeen cobbles of local Citronelle chert material were found that display clear evidence of modification via flake removals. The presence of flaked cobbles and exhausted bifaces at the same site is suggestive of a full continuum of knapping activities, or at the very least, indicates that reduction trajectories included formalized bifacial tools.

Approximately one kilometer south of 22FO1515 is 22FO1545. Very little was recovered besides debitage, but one proximal fragment of a stemmed biface and one flaked cobble were found in surface collection. Mechanical stripping identified twelve baked clay features arranged in a linear pattern and spanning a fifty meter area. Because most of the artifact bearing soil had eroded away and given the general lack of integrity, determinations regarding site function were not possible (Jackson 2012).

22FO1546 sits roughly 100 meters south of 22FO1545, on an adjacent ridge above Davis Creek. Its close proximity to 22FO1545 advances the possibility that they were occupied concurrently by members of a single group or related groups. Similar to the other two, this site produced two low fired baked clay hearth features. Like 22FO1515, a variety of chipped stone tools of Citronelle gravel were recovered, including one distal end of a formalized projectile point/knife, three retouched flakes, and four unfinished biface or biface fragments (Jackson 2012). One formalized end scraper of non-local high quality pink chert, dating to the late Paleoindian or early Archaic period was also recovered. The diversity and size of the assemblage suggests that 22FO1546 was a residential site that was occupied over multiple time periods.

Research Goals

The present research is focused on the analysis of knapping experiments using locally available stone tool material so that stone tool production of past inhabitants of the Mississippi Pine Hills may be better understood. The significance of this study is two-fold. First, the analyses generated in this study are valuable in understanding local adaptations, in both environmental and social contexts, of prehistoric Pine Hills inhabitants. Taking the small nature of raw lithic material into consideration, the relationship between initial cobble size and debitage profiles has warranted further exploration. The data presented here contributes significant understanding to the current knowledge of local lithic studies. Moreover, the analytical methods employed are designed to test previously identified methods of processing lithic assemblages. While these methods have proven useful in some respects, they have not been tested stringently with regard to the nature of raw lithic material. The present research holds the capacity for further refining these methods as well as identifying specific variables that are and are not suited to analysis of Citronelle gravel chert assemblages. The present research also carries the possibility of application to similar gravel cherts in other localities.

CHAPTER II - NATURAL ENVIRONMENT AND CULTURAL HISTORICAL BACKROUND

The Pine Hills region is marked by a distinctive geological and biological environment which differentiates it from surrounding regions. A summary of the natural environment is presented in this chapter. Following this, an overview of the cultural historical framework is presented, with focus placed on lithic scatters within the Pine Hills.

Environmental Setting

Geomorphology

All three sites used for comparison in this study are located in the Pine Hills physiographic region, which is located within the larger Eastern Gulf Coastal Plain. This area is characterized by a rolling topography that can range from 300 to 500 meters above mean sea level (Cross and Whales 1974). The rolling landscape is separated by steep V-shaped ravines of up to 30 meters below the hilltop. Many tributaries break up the landscape and feed into larger drainages, including the Pascagoula, Leaf, and Chickasawhay Rivers which divide the region into major alluvial flood plains (Fields and Hudson 2007).

Sands, gravels, and clay deposits characterize the surface and near surface geology within the Pine Hills. These deposits date to the Miocene, Pliocene and Pleistocene epochs. The geologic units recognized in this region are the Catahoula, Hattiesburg, Pascagoula and Citronelle Formations (Fields and Hudson 2007:6). Fine to medium grained sand and ferruginous sandstone, along with differing amounts of gravel, compromise the Catahoula Formation (Jackson 2012). The ferruginous sandstone can often be found at the boundaries of the Catahoula and later deposits, formed by oxidative processes. Lying on top of this are the Hattiesburg and Pascagoula Formations, respectively (Fields and Hudson 2007:7). These layers date to the Miocene and are composed of thin clay silt in the former, and a mixture of clay silt and gravelly sand or sand in the latter (Brown et al. 1944). The Pliocene-aged Citronelle Formation is comprised of silty sand, clayey sand and sandy gravel chert deposits, and exists at the top of the hills and ridges that span the landscape (Fields 2001, Kelley 1974:7).

Lithic Resources

Several types of workable tool stone have been recovered from archaeological sites in the Pine Hills region. Identified materials include Tallahatta sandstone, Citronelle gravel chert, quartz, silicified sandstone, Coastal Plain agate, and Coastal Plain chert.

Tallahatta Sandstone. Tallahatta sandstone (sometimes called Tallahatta quartzite or TQ) is a sedimentary sandstone consisting of fine to medium sand grains cemented together by opal and chalcedony (Heinrich 1987). Although not metamorphosed, the use of the term "quartzite" was based on the fact that constituent grains of sand can be observed with fracture planes running through them rather than around them due to the cementation material. Tallahatta sandstone has a grainy, sandy texture and varies in the degree of silica present in each specimen (Heinrich 1987, 1988; Lehman 1989). Varieties include well cemented material as well as others that are friable and more susceptible to the effects of weathering (Heinrich 1988). Colors can include a medium gray, light blue, and white to almost translucent with a speckled, pepper-like appearance throughout the material. The salt-and-pepper appearance results from inclusions of feldspar and glauconite (Heinrich 1988; Lehmann 1989; O'Hear and Lehmann 1983). The Tallahatta

Formation from which knappable material was quarried is oriented in an arc running south from the southwestern portion of Tennessee through central Mississippi down into south Alabama. (Lehmann 1989; O'Hear and Lehmann 1983). Eocene marine sediments of siliceous claystone and mudstone from the depositional layers and are overlain by glauconitic and ferruginous sands and clays (Keith 1998; O'Hear and Lehmann 1983).

Citronelle Gravel Chert. Citronelle cherts are a fine to coarse grained, cryptocrystalline material. The morphological characteristics of Citronelle gravel vary according to parent material types but occur locally in the form of pebbles and cobbles that were originally deposited during the Pliocene or Pleistocene epochs. Citronelle gravels are part of the Citronelle Formation (shaded light pink in Figure 1) running through south Mississippi and represent the most abundant lithic resource suited to knapping. Streambeds, gravel bars and remnant ridge top deposits comprise the most frequent source areas. Citronelle gravels also include minor amounts of chalcedony, agate, and jasper, as well as sandstone, quartz and quartzite (Stallings 1989). Citronelle cherts range in color from dark brown and gray/light gray, to very pale brown and tan/yellow (Keith 1998; Stallings 1989). Heat treatment was often used on Citronelle chert as a means of improving the knapping qualities. Such thermally altered chert is capable of producing a dark red to light pinkish red color and a glossy internal surface quality when flaked (Collins 1984; Jackson 2012; Perkins 1985).

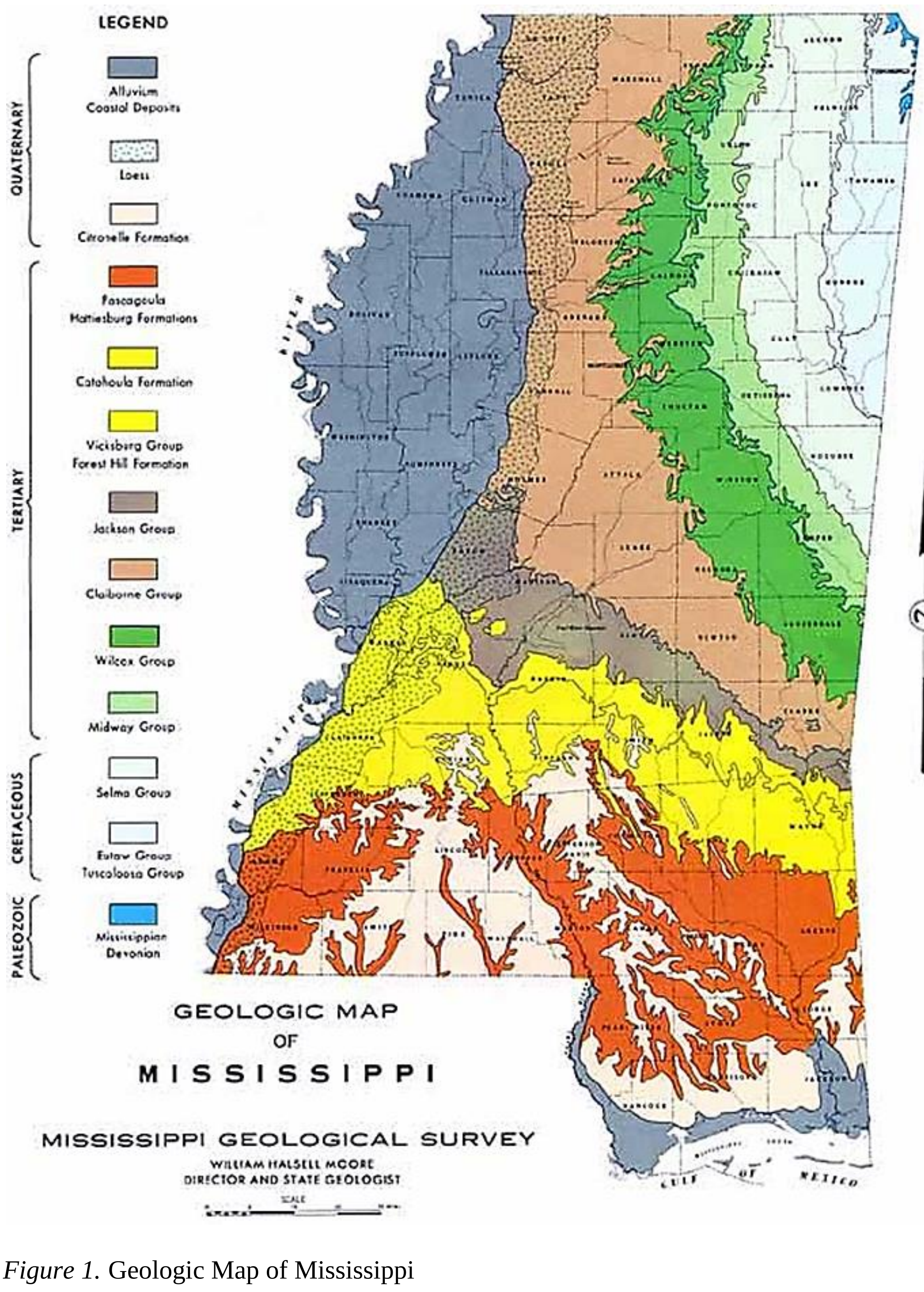

Figure 1. Geologic Map of Mississippi

Note: Geologic Map of Mississippi. (1976) Mississippi Geological Survey. Jackson, Mississippi.

Quartz. Quartz is a fine-grained material formed in thin veins of metamorphic rock formations of the Alabama piedmont. Quartz may also be found in the Lime Hills of southwestern Alabama in the form of large cobbles in stream beds (Jeter and Futato 1990). For this study area, smaller pebbles are also found among deposits of Citronelle gravel cherts. Quartz is primarily thought of as a product of metamorphism of quartzite material, yielding morphological characteristics that include unpredictable fracturing, varying sizes, and variations in hue. Colors can range from a milky white opaque to clear, almost translucent quartz, as well as hues of pink (Prinz et al. 1977).

Sandstone. Ferruginous (or silicified) sandstone is a fine to coarse-grained material that is solidified by iron oxide. This material can range in color from black to deep purple, likely resulting from the iron oxide silica cementation, and displays moderate conchoidal fracture patterns (Heinrich 1987). It is a characteristically hard, nearly quartzitic material, and such qualities make ferruginous sandstone fairly susceptible to controlled knapping, though its use is thought to be restricted to Middle and Late Archaic assemblages (Jackson 1995; Keith 1998, Reams 1995). Knappable ferruginous sandstone occurs, with rarity, throughout southeast Mississippi and southwestern Alabama as inclusions within non-ferruginous or low-quality deposits and gravel bars (Keith 1998; Lumpkin 1994; Reams 1995).

Coastal Plain Agate. Coastal Plain agate is a fine-grained, translucent form of variegated chalcedony. The general appearance is usually a cloudy, banded coloring mottled with various shades of blue, purple, gray, black, and pink (Ensor 1981). Agate is found in thin laminated beds and cavities of other material types such as siltstone and Coastal Plain chert. It is frequently found mixed or alternating with opal quartzites such as Tallahatta quartzite. In such instances, agate is often the outer cortex and may contain fossil remnants of marine organisms (Dunning 1964). Agate is found mainly in the southern Coastal Plain of Alabama.

Coastal Plain Chert. Coastal Plain chert is described as a lightweight silica rock. Like Coastal Plain agate, Coastal Plain chert is found in laminated layers within the Tallahatta formation often associated with TQ (Hastings and McVay 1962). It occurs as veins as much as five feet in thickness and is recorded as the thickest part of the Tallahatta formation. Layers may vary slightly in grain particle sizes and mineralogical composition (Hastings and McVay 1962).

Floral and Faunal Resources

The Pine Hills region partly derives its name from the predominance of longleaf pine forests in the area during prehistory (Delcourt and Delcourt 1980). This ecosystem was established by 5000 B.P. (Brown et al. 1996) and is marked by dispersed longleaf pine stands with fairly open canopies and savannah-like understories. The ample room and light reaching the ground allowed species such as gallberry (*Ilex glabra*), persimmon (*Diospyros virginiana*), and yaupon holly (*Ilex vomitoria*) to flourish. At lower elevations, heterogeneous forests of Slash (*Pinus elliotti*), Loblolly (*Pinus taeda*) and Shortleaf pine (*Pinus echinata*) were common (DeLeon 1981).

Along the upland areas of southeast Mississippi, mixed pine-oak forests are common. These are located in more easily drained, sandy soils with sparse vegetation. Here, lichens and herbs as well as prickly pear cactus (*Opuntia humifusa*) and various scrub oaks inhabited the area amongst the sparse pines (Fields 2001:11).

Heterogeneous pine-hardwood forests exist in the various water drainages, such as ravines and bottomlands. Sweetgum, magnolia, and cypress were present (Cross and Wales 1974, Fields 2001). Several potential calorie sources for indigenous populations rested in the floodplains and stream bottoms. Nut-producing taxa included multiple species of oak (*Quercus* spp.), pecan (*Carya illinoisensis*), and hickories (*Carya* spp.). The understory would have provided fruit resources, including mulberry (*Morus rubra*), muscadine (*Vitus rotundifolia*) and mayhaws (*Crataegus aestivalis*) (Jackson 1995). Botanical data collected from sites in Greene County indicate exploitation of multiple wild taxa, including hickory nut, wild plum, honey locust, passionflower, grape and sumpweed (Fields 2003:335). To date, no evidence of plant cultivation in the Pine Hills exists, though knowledge of plant husbandry would have likely been available to local populations (Jackson 2012).

Due to the highly acidic soil conditions of the Pine Hills region, animal remains in archaeological contexts are scarce, but many upland woodland and floodplain species would have been available. Whitetail deer (*Odocoileus virginianus*), squirrel (*Sciurus* spp.), raccoon (*Procyon lotor*), rabbit (*Sylvilagus* spp.), turkey (*Meleagris gallapavo*), and opossum (*Didelphis marsupialis*) remains have been documented in other parts of the southeastern U.S. and would have found ample sustenance in local acorn producing flora (Jackson 1995, Jackson and Scott 2002). Several varieties of reptiles, such as snakes, lizards, alligators and the now endangered gopher tortoise (*Gopherus polyphemus*) would have been widely available as well, due to the highly sandy soils (Keith 1998). Fish taxa found in larger waterways would have included gar (*Lepisosteidae*), catfish (*Ictaluridae*), suckers (*Catostomidae*), bowfins (*Amiidae*), and bass (*Lacepedae*) (Cross and Wales

1974). In smaller streams and creeks, sunfish (*Lepomis* spp.), shiner (*Notropis* spp.), and pirate perch (*Aphredoderus sayanus*) were common (Fields 2001). Seasonal waterfowl would have included geese and ducks, while resident species like blue heron (*Ardea herodias*) would both have been available (Jackson 2012).

Cultural Historical Framework

The prehistoric chronology of southeastern North America is broadly divided into six stages. These are: Paleoindian, Archaic, Gulf Formational, Woodland, Mississippian, and Protohistoric. Here, the chronological stages relevant to this thesis are presented, which include the Paleoindian through Woodland stages. The use of stone tools persisted into the Mississippian and Protohistoric periods; however, the sites under comparison in this study have been dated to the Woodland period, and consequently, this will receive the majority of attention. Therefore, post-Woodland cultural stages are not considered here. Within the stages presented, the dominant settlement patterns and technological organizations are the center of discussion, with a focus on previous studies of flake scatters within the Pine Hills region.

Paleoindian Stage

The earliest occupation of eastern North America occurred during the Paleoindian stage, between 15,000 and 12,000 B.P. (Anderson and Sassaman 1996). While multiple models have been suggested for the initial spread of Paleoindian peoples, Mississippi saw its first settlers move in from the north. McGahey (1996) has shown that roughly 70 percent of the early and middle Paleo-Indian projectile points are located at the northern end of the state. Because of the highly acidic soil conditions of the Southeastern region of North America, preservation levels for organic material remains are scant, but patterns in lithic tool scatters show a highly mobile, hunter-gatherer subsistence economy. Because of their mobile lifestyle, it is likely that the Early to Middle Paleoindian inhabitants remained close to herds of Pleistocene megafauna, learning the local migration patterns as well as exploiting new floral resources.

While the majority of stone tools of this era are of non-local varieties, the occasional recovery of locally-made Clovis projectile points indicates some residential usage of the Pine Hills region through the Middle Paleoindian stage. These points are often identified by a specific flaking pattern termed "fluting," wherein an objective piece is shaped into a lanceolate form by flaking from edge to edge perpendicularly on each face. Then, channel flakes are removed down the middle of the point that allow for it to be firmly hafted to the end of a spear. Such locally made points have been found in Jones, Perry and Stone Counties by both archaeologists and private collectors (Jackson and Scott 1992; McGahey 1996; Padgett and Heisler 1979:9; Tesar 1974). These highly curated tools are the hallmark of Early and Middle Paleoindian tool kits, which also included side scrapers, drills, spokeshaves, denticulates, adzes, and gravers (Anderson 1996).

Late Paleoindian Period (10,500-10,000 B.P.). The first significant wave of immigrants to arrive in south Mississippi was late in the Paleoindian stage. In contrast to those that came before, Late Paleoindian projectile points recovered in Mississippi are smaller, lanceolate tools and are often made of local material. Varieties include Dalton and San Patrice (Geiger 1980). These are found across southern Mississippi, and their relative frequency suggests a population increase accompanied by a more equitable distribution of people across the landscape (Anderson 1996). In the Pine Hills region, sites generally display low tool diversity and likely represent a task specific or limited purpose location (Keith 1998). Corresponding residential base camps may have been located in the lower floodplains.

One of the more prominent Late Paleoindian sites in the Pine Hills is the Beaumont Gravel Pit (22PE504) (Giliberti 1995). Located on the natural levy of a former Leaf River channel, this site was used as a quarry for local Citronelle gravel material between the Late Paleoindian and Early Archaic periods. Alongside copious amounts of locally-sourced manufacturing debris, excavation produced multiple exhausted bifaces and other tools of non-local materials. Tools made of Tallahatta sandstone, ferruginous sandstone, and non-local cherts were brought to the Beaumont Gravel Pit site and discarded in the course of rearmament activities. This pattern suggests that highly mobile, long range hunter-gatherers made use of the site during their seasonal migrations over the course of multiple generations. Other Late Paleoindian sites located in the Pine Hills, such as the Sims site (22FO582), have been reported (Jackson 2012). Four Dalton points were recovered from a site in Jasper County (22JS587) located within the floodplain of the Tallahalla-Naukfuppa creek system (Atkinson and Elliott 1979). These were all found between 70 and 80 centimeters below the surface and represent a single occupation. The Kittrell Site (22JO788) located near Laurel, Mississippi produced San Patrice and Dalton points, as well as thumbnail scrapers, from a Late Paleoindian component (Fields 2001). One Dalton fragment was identified at the GWO site (22JO568) in Jones County (Jackson and Scott 1992). Another possible Late Paleoindian occupation was identified by Keith (1998:91) at the Sandhill site (22WA676). The recovery of an exhausted unifacial end-scraper and a flaked Citronelle gravel cobble at the base of cultural material-bearing strata led to the conclusion that a limited-purpose, short-term encampment existed here at some point. This conforms to the theory that smaller, upland sites were special purpose, task-specific locations created in the course of resource collection activities.

Archaic Stage

Around 10,000 B.P., a global warming event called the Younger Dryas came to a close and the Holocene Epoch began. This change in average temperature produced greater seasonal climatic shifts than those seen today; summers were hotter and dryer while winters were colder and wetter (Schuldenrein 1996). Culturally, this time is characterized as a continuation of the highly mobile hunter-gatherer adaptations of the Pleistocene, including technological organization (Bense 1994; Smith 1986). Groups continued to move seasonally, but generally remained within more fixed ranges.

Early Archaic Period (10,000-8,000 B.P.). A semi-permanent settlement pattern emerged during the Early Archaic in which groups would stay nearer to major river systems during the summer and fall months (Smith 1986). This allowed them to take advantage of the aquatic and floral resources available. During the winter and spring, wetter conditions caused frequent flooding. This would have likely made for an unfavorable residential environment, so groups are thought to have spread out into the hills. Group dispersal was probably also a necessary one as the primary economic system in place was based on subsistence. People needed to ensure enough food for all members to eat, and larger aggregations were more difficult to sustain in the cold winters (Smith 1986). Therefore, people were moved to resources rather than resources being moved to people.

In terms of technological trends, projectile points display a progression of features, evolving from the "classic" Dalton form. Hafting elements developed from basal edge grinding to side notching to triangular corner notching. Basal morphologies became bifurcated and later square or contracting stemmed (Anderson et al. 1996; Smith 1986; Steponaitis 1986). As new morphologies developed, distinct but related styles came into prominence. Projectile points such as Big Sandy, Cache River, Taylor, Bolen, and Hardaway are thought to be descended from Dalton traditions (Steponaitis 1986:370-371). In the Pine Hills, these types are almost always made from local gravel chert or Tallahatta sandstone (McGahey 1996). A host of groundstone implements also appear during the Early Archaic, including mortars, axes, and anvils (Bense 1994:69), which signal a greater reliance on floral resources than before.

Multiple Early Archaic projectile points have been recovered from the Beaumont Gravel Pit site (22PE504) (Giliberti 1995), as well as 22GN639 (Brown et al. 1997). At the Sandhill site (22WA676), Keith (1998) interpreted the highly diverse tool material types within the Early Archaic component as a production of highly mobile occupants. Excavations at the G.W.O. site (22JO568) produced multiple utilized sandstone implements that likely served in the processing of plant materials (Jackson and Scott 1992). This indicated to the authors that the site was used over an extended duration or may have been habitually reused with sufficient regularity to warrant a cache of "site furniture" (Jackson and Scott 1992:73).

Middle Archaic Period (8,000-6,000 B.P.). Within the Holocene Epoch, the climatic episode known as the Hypsithermal brought about a generally warmer, dryer climate (Schuldenrein 1996; Smith 1986). Increasing sea levels resulted from receding ice sheets and caused a shift in major river systems across the region. Rivers that were previously fed by melting glaciers now transitioned into more predictable, meandering systems fed by rainfall (Fields and Hudson 2007) For the Pine Hills, rainfall and erosion created braided streams and tributaries that dissected the loess soil. These fed into the larger river systems and slowly began forming the upland toe ridges seen today. Oxbow lakes and backwater swamps were eventually formed as a result of slowing river systems (Smith 1986:22). These changes in riverine habitats created new means of resource exploitation and new cultural adaptions soon followed. Much of the local gravel cherts were buried under flood deposits, so local populations relied more on imported raw materials, such as Tallahatta sandstone, Coastal Plain Agate, Coastal Plain Chert and Silicified Sandstone (Brookes and Reams 1996; O'Hear and Lehmann 1989). Projectile point types from this period include Cypress Creek, Alachua, White Springs, and Morrow Mountain (McGahey 2000).

Materially, evidence for Pine Hills occupations during the Middle Archaic is restricted to isolated projectile points and relatively small sites. The Middle Archaic component at Tanya's Knoll (22WA642) is represented by a single Alachua point of ferruginous sandstone (Fields 2002; Reams 1996). Similarly, the Middle Archaic occupation at Burkett's Creek (22FO748) is represented by lone projectile point of ferruginous sandstone (Jackson 1995). Several Crane points of various local and non-local materials have been reported from excavations at 22PE668 in the DeSoto National Forest (Fields 2001).

Late Archaic Period (6,000-3,000 B.P.). By roughly 6,000 BP, modern climatic conditions had been established (Bense 1994:85), and with them, a shift in cultural patterns emerged. Sea levels rose to their current state between 5,000-3,000 B.P., forming barrier islands and modern coastal ecosystems (Bense 1994:85). In the Southeast, the domestication of several indigenous plant species led to a "hunting-gathering-gardening complex" that allowed for greater population increases that ever before (Jackson 2012:24). Within the Pine Hills, however, groups appear to have retained a more or less exclusive reliance on wild species (Jackson 2012). Various stemmed or corner notched projectile points are characteristic of this period. Locally, the most common types include Pontchartrain, Flint Creek, and Gary, Kent, Shumla, Edwards, Little Bear Creek, Ledbetter and Carrolton (Gilliberti 1994).

Settlement patterns show a distinct shift towards longer durations of encampment as a result of population pressure during the Late Archaic (Smith 1986). In the Pine Hills, this is recognized archaeologically by the increase in the number of sites containing Late Archaic components (Fields 2003). The Jeff Parker site (22FO608), located in Forrest County, Mississippi, produced intact, distinguishable deposits from the Late Archaic, Middle Woodland and Late Woodland time periods (McMakin 1995). Located in the upland hills, the inhabitants of the Jeff Parker site relied on both formally curated tools and expedient ones. When combined with evidence of fired clay and copious manufacture debris from tool production, formalized tool manufacture was interpreted here as a sign of residential activity that occurred over several seasons (McMakin 1995). At Augusta Bluff (22PE543), located on a bluff next to the Leaf River, Wright (1982, 1984) recovered evidence of multiple hearths and a Citronelle gravel based lithic industry, including Pontchartrain, Kent, and Gary projectile points. Within the Camp Shelby Joint Forces Training Center in Forrest County, at least one Gary point was found during systematic survey, along with evidence of tool manufacture debris. Located at the top of a toe ridge, it most likely represents a short term collector camp (Fields, personal communication).

Gulf Formational Stage

The Gulf Formational stage has, in the past, been split into either Late Archaic or Early Woodland. However, Walthall and Jenkins (1976) have identified significant socio-technological developments emerging during this time that distinguish it from stages occurring before and after. These authors define this stage by the advent and propagation of ceramic paste technology in the southeastern United States. As this technology spread westward across the Southeast, the ways of life for inhabitants of the region were transformed. Overall, the Gulf Formational stage is one of transition from the terminal Late Archaic to the initial Early Woodland.

Early Gulf Formational Period (4,500-3,200 B.P.). In the early portion of this stage, pottery technology that originated around the Georgia/South Carolina and north Florida coast spread westward across the southeast. The earliest pottery was made using vegetable fibers as a tempering agent, and was shaped into basic bowl and beaker forms (Sassaman 1993:16). Before this point, prehistoric peoples had been using various types of stone vessels, such as steatite or soapstone, for use in cooking or heating (Sassaman 1993). These were heavy to move and time consuming to make; both issues being alleviated by the advent of ceramic paste. In the Pine Hills, life ways of local peoples largely remained unchanged from the Late Archaic. Settlement patterns seem to be based around larger base camps and were located near rivers in the spring and summer. In the fall and winter, smaller encampments were located further into the uplands (Bense 1994; Brown et al. 1996; Walthall 1980).

Middle Gulf Formational Period (3,200-2,600 B.P.). By 3,200 BP, pottery made its way into Alabama and Mississippi from the Tennessee River Valley via the Tombigbee drainage (Jenkins and Krause 1986; Morgan 1992).Plain, undecorated Wheeler series ceramics are the earliest forms found in the Pine Hills, and are mostly concentrated in the eastern most counties (Jackson et al. 2002). These ceramics have been recovered at several Middle Gulf Formational sites, including the Sandhill Site (22WA676) and 22WA678 (Keith 1998). Other sites with recorded Wheeler ceramics are found in the Black Creek District of the DeSoto National Forest (Jackson et al. 2002).Identified lithic remains from the Middle Gulf Formational are mostly comprised of local materials. For the Pine Hills, Citronelle gravels dominate the recovered assemblages, although Tallahatta sandstone and other non-local materials are present (Fields and Hudson 2007; Jackson 2012). Projectile points tend to be smaller and display less variability.

Late Gulf Formational Period (2,600-2,100 B.P.). In keeping with the overall trend, the Late Gulf Formational period is defined by further refinements in ceramic paste technology and style. Sand and grog (ceramic) gradually replaced fiber as a tempering agent in the Pine Hills, and new vessel forms, including podal supports, became widespread (Jackson et al. 2002). Three distinct ceramic traditions emerged during this time: Alexander between the Tennessee River Valley and Gulf Coast, Bayou La Batre in the Mobile Bay area, and Tchefuncte in coastal Louisiana and Lower Mississippi Valley

(Jackson et al. 2002; Keith 1997). Because the Pine Hills is located between all three of these cultural areas, local inhabitants likely had some interaction with each.

Based on lithic assemblages from this time, seasonal mobility ranges appear to have decreased. Tallahatta sandstone and Coastal Plain chert were gradually abandoned in favor of local gravel material. Keith (1998:154) argues that this increase in local material utilization is a signal of increasing sedentism. McMakin (1995) observed that stone tools at the Jeff Parker site (22FO608) in Forrest County, Mississippi were heavily formalized and curated. When comparing debitage from this site to the Late Archaic Robinson site (22FO580), McMakin (1995) found that a higher ratio of bifacial thinning flakes to flake debitage points to a logistically-oriented collector lifestyle. Smaller sites in the Pine Hills reinforce this hypothesis. Jackson (1995) argues that a Late Gulf Formational component at Burkett's Creek (22FO748), identified by the recovery of multiple Pontchartrain and a single Flint Creek point, represents a short term foraging camp. Dunn (1999:85) made a similar determination regarding the Swamp Child site (22FO666) a site overlooking the Black Creek drainage.

Woodland Stage

Because the Gulf Formational stage encompasses what was traditionally thought of as the Late Archaic and Early Woodland period, discussion will continue with the Middle Woodland period.

Middle Woodland Period (2,100-1,500 B.P.). The Middle Woodland period is characterized by increasing inter-regional social interaction, recognized in the appearance exotic trade goods, ceremonial mound construction and recurring ideological imagery on ceramic vessels. The Hopewellian interaction sphere (or Hopewell ceremonial complex) represents the pinnacle of this phenomenon (Bense 1994). Items traded within this exchange system include non-local tool stone, copper items, galena, mica and complex mortuary motifs (Bense 1994). Local participation in this network is mostly seen in three independent, but related, cultural areas: the Marksville culture found in the Lower Mississippi Valley, the Porter Middle Woodland culture found in the Mobile Bay, and the Miller II culture of the Tombigbee River area (Blitz and Mann 2000; Jackson et al 2002; Walthall 1980; Jenkins and Kraus 1986). The Pine Hills region is bordered by each of these, and evidence of interaction with all of them has been recorded at local sites in the form of decorated ceramics (Brown et al. 1996; Keith 1997; Jackson et al. 1999; Jackson et al. 2002). The most commonly reported ceramic types are those associated with the Marksville and Porter cultural phases, which some have suggested represents a "continuum of east-west interaction in the Pine Hills and along the Gulf Coast" (Jackson 2012:28). Fields (2007) defined the Mossy Ridge Zone Incised ceramic type, which may represent a local manifestation of this inter-regional cultural interaction.

Ceremonial earth mound construction activity that was absent from the Pine Hills during the Late Archaic was not similarly so during the Middle Woodland. Currently, only a handful of such mounds exist within the region, but these are representative of the larger temporal trend of increasing mound construction in general. McQuorquodale Mound in Clarke County, Alabama and McRae Mound in Clarke County, Mississippi show signs of Hopewellian influence in the form of copper artifacts and mound construction, respectively (Blitz 1986:30; Wimberly and Tourtelot 1941). The construction of the Deadly Silent Mound in Forrest County, Mississippi was dated to between 1923 and 1543 B.P. (Jackson 2012).

While settlement patterns during the Middle Woodland indicate variable reliance on both collector and forager adaptive strategies, a general trend towards increasing sedentism likely resulted in a greater reliance on collector systems. The Middle Woodland occupation of 22PR533 indicates that it was a short term resource extraction camp inhabited during the fall or winter (Brown et al. 1996:433-434). Lithic remains were comprised of expedient flake tools and projectile points similar to earlier Late Archaic occupations. However, greater diversity in artifacts and features, and several possible hearth features suggest longer term occupations (Brown et al. 1996). Keith (1998) interpreted Middle Woodland remains at the Sandhill Site (22WA676) as reflecting a decrease in mobility and increasing sedentism. A higher reliance on local gravel cherts and greater amounts of lithic debitage led to the conclusion that this site was a residential base camp that functioned within a logistical collector system (Keith 1998). Jackson et al. (2000) have argued that prehistoric occupation within the Pine Hills may have reached its zenith during the Middle Woodland because an increase in reported sites is interpreted as an increase in local populations.

Late Woodland Period (1,500-800 B.P.). The earliest portion of the Late Woodland time period shows signs that the long distance trade networks of the Middle Woodland experienced a gradual decline. In this wake, an increase in territorial definitions and intra-regional networking take hold (Johannessen 1993; Nasseney and Cobb 1991; Smith 1986). Ceramic construction in the Pine Hills seems to have been dominated by cordmarked decorations and the use of grog as a tempering agent. This is understood to be part of a region-wide classification, called the “Baytown variant”, which runs from northwestern and central Alabama west to the Lower Mississippi Valley

(Jenkins 1981:25; Jenkins and Krause 1986). Many Late Woodland sites have also produced Middle Woodland ceramics (Jackson 2012). Though these two wares are distinct, this pattern may reflect continuous occupations between the two time periods.

One innovation during the Late Woodland that fundamentally changed the way of life for local inhabitants was the adoption of bow and arrow technology. Blitz (1988) identifies the Collins point type as the first evidence of true arrow points in southeast Mississippi. After the appearance of this technology, a progressive decrease in projectile point style and the genesis of smaller, triangular arrow points has been noted for the area (Jenkins 1982). This suggests that the bow and arrow quickly replaced the atlatl as the dominant projectile technology in warfare and animal harvesting, likely due to its accuracy and portability.

Settlement systems reflect a continuation of trends found in the Middle Woodland. Greater reliance on collector organization and special purpose task groups can be seen in the Pine Hills. Analysis of the lithic remains related to the Woodland component at the Oo-Oo-Lation site (22GN688) showed high degrees of core reduction along with a wide range of specialized tool production. This was interpreted as a residential base camp where formal tools could be made and taken off-site for specific tasks. Tools used on-site would have been expediently made and thrown away (Fields 2000). Contrasted with this was Tanya’s Knoll. Here, the narrow range of specialized tools and remnants of bipolar core reduction indicate that the time spent at this site was relatively brief, and activities performed here were limited in scope. The very low incidence of middle and late stage flakes indicate that the specialized tools used on-site were manufactured and maintained at another location; most likely a site similar to the

Oo-Oo-Lation site (Fields 2000). Another proposed limited-use site is the Chief Cato site (22FO1023) in Forrest County. Here, a high percentage of early stage flakes and limited evidence of bifacial manufacture is interpreted as a short-term encampment. The absence of cores lead Jackson and Wright (2000) to the conclude that objective pieces were brought to the Chief Cato site, reduced, then transported off-site for use.

The presence of bipolar core reduction at Tanya's Knoll is key to the interpretations drawn from this site. Because of the unpredictability of bipolar flake production and the small initial nodule size of the Citronelle gravel material, the production of biface technology can be ruled insignificant, if not incidental, in such circumstances because of the care required for such activities. Its comparison to the Oo-Oo-Lation site reinforces this conclusion, as it lacks the assemblage profile of residential site activities.

Towards the end of the Late Woodland, populations in the major river valleys and basins increased as mound centers were constructed and enlarged (Nassaney and Cobb 1991). The Pine Hills continued to go through cultural shifts, but the way of life for most groups remained roughly the same: a hunter-gatherer subsistence system based on logistical resource collection and residential bases with defined territories. By 1,300 B.P., prehistoric groups across the Southeast came to rely increasingly on agriculture, especially in the American Bottoms, but this remained largely absent from Pine Hills populations (Johannessen 1993:66; Smith 1986:50-51).

Summary

While multiple climatic events have drastically altered the Pine Hills landscape through time, this area of Mississippi was able to maintain a high degree of biodiversity, which allowed for a sustained hunter-gatherer lifestyle amongst local peoples for thousands of years. Both local and non-local tool stone resources were utilized, including Tallahatta sandstone, Citronelle gravel chert, silicified sandstone, Coastal Plain agate and Coastal Plain chert. Currently, knowledge of prehistoric settlement patterns is limited to a select few excavations and theses. However, a growing trend in the data indicates continual habitation of the Pine Hills, at least seasonally, since the Late Paleoindian time period. Paleoindian groups appear to have made occasional use of the region. Archaic inhabitants made more regular use of the Pine Hills in the form of highly mobile, kin-based groups of hunter gatherers. Woodland settlement patterns display greater degrees of complexity and variability. Overall, the use of non-local tool stone declines in favor of local gravel cherts. This is seen as the result of increasing populations, decreasing seasonal mobility and the definition of territorial boundaries.

CHAPTER III - THEORETICAL CONSIDERATIONS

This chapter presents a summary of relevant theories regarding prehistoric hunter-gatherer technological organization and settlement patterns. The various analytical studies explored here are interpreted from within the organization of technology approach, with specific attention paid to stone tool production strategies. Following this is a summary of different types of debitage analysis and their utility in interpreting archaeological data.

The Organization of Technology

The organization of technology approach to understanding past human tool use patterns stems from the work of Lewis Binford (1978, 1979, 1980, 1982, 1983). By employing ethnoarchaeology, Binford (1980) was able to link assemblage variability to both climate and the distribution of resources across the landscape by formulating two models of resource procurement systems that can be tied to site formation. These he labeled collector and forager models of resource exploitation. In a collector model, where the resource target is premeditated or known, tools employed will be more formalized and limited in specificity of use, otherwise termed "coarse-grained" assemblage variability (Binford 1980). This is distinct from forager models, whose expected resource type or encounter is not known or cannot be predicted with sufficient confidence. In such cases, tool form will be more generalized so as to meet a wide range of needs that may arise during procurement activities. The resultant assemblage variability is considered "fine grained" (Binford 1980).

These models of mobility patterns were later elaborated upon by Robert Kelly (1988) in his discussion of bifacial lithic technology. Kelly (1988:717) defines the organization of technology as, "the spatial and temporal juxtaposition of the manufacture of different tools within a cultural system, their use, reuse, and discard, and their relation not only to tool function and raw-material type and distribution, but also to behavioral variables which mediate the spatial and temporal relations among activity, manufacturing, and raw-material loci." Using this framework, Kelly demonstrates how the collector and forager models of mobility will produce distinct lithic signatures in the archaeological record. This definition was later refined by Margaret Nelson (1991) as a hierarchical diagram, where environmental conditions sit at the top and artifact distribution and form sit at the bottom. Between these, Nelson positions social and economic strategies, technological strategies, tool design, and artifact distribution as mediating factors in the trajectories of the life of a lithic tool (Nelson 1991).

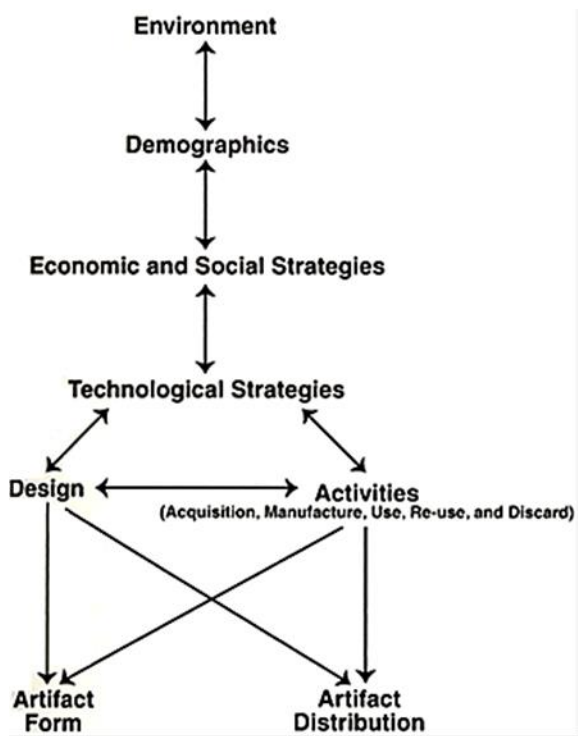

Figure 2. Organization of Technology Flow Chart

Reproduced, with permission, from Carr et al. (2012:7).

Most recently, Carr et al. (2012) have reevaluated Nelson's (1991) diagram by recognizing the influence of demographic variability in the formation of archaeological assemblages (following Cohen 1985; Keeley 1988). Carr et al. (2012) also make the addition of bidirectional flows between each hierarchical level in the diagram (Figure 2). This accounts for the demographic impact upon the environment and the potentially resulting changes in social and economic strategies. This bidirectionality, as the authors describe, similarly affects the relationship between technology and social and economic strategies, as is demonstrated by the adoption of bow and arrow technology across North America (Carr et al. 2012:8).

Technological Strategies

As discussed previously, the technological strategies employed in the production of lithic tools can broadly be grouped into two categories: expedient and curated (Andrefsky 1994; Binford 1979; Kelly 1988). While these two categories serve as a classificatory scheme in understanding the use of lithic resources, it is worth noting that they are largely seen as the endpoints of a continuum. The resulting assemblage will therefore reflect varying proportions of reliance on one extreme or the other, and the mix of strategies employed from this continuum is subsequently born out of a wide range of site conditions, target resource and environment. Thus, "the dynamics associated with lithic tool production processes have implications for stone tool typology as it relates to tool design, function and formal qualities" (Andrefsky 2005:34). However, as Andrefsky (2005:31) also writes, "The amount of effort expended in stone tool production is critical for understanding tool production processes."

An expedient technology is one that requires minimal effort or planning in its production. This type of tool is normally produced on-site and is discarded after its need has been served (Andrefsky 1994; Binford 1979). Cowan (1999) writes that the most expedient method of stone tool production is the detachment of flakes from a parent core. Such a method produces a tool with extremely sharp marginal and distal edges, and which is capable of performing several tasks, including scraping and cutting. However, while the production costs are low, these tools have poor multifunctional utility, high hafting costs and consume raw material at a comparatively faster rate. Moreover, expedient flake tools have sharp but fragile edges, making them unsuitable for transport. In a similar respect, parent cores are not viable portable gear either, as they are often too bulky to transport over substantial distances (Kuhn 1994; Nelson 1991). Therefore, expedient technologies are more likely utilized when tool transport is not a decisive factor in the completion of a task. Some researchers have understood this trajectory to be associated with low residential mobility and the stockpiling of raw material (Parry and Kelly 1987); however, Andrefsky (1994) found that expedient technologies can be expected where the distribution of lithic resources across the landscape is fine-grained, meaning that tool producers need not travel far off-site to procure raw material.

On the other end of the continuum lies curated technology. This technology is characterized as being both durable and reliable, and is purposefully shaped into a form designed to complete a specific task. This specialization often requires more care and precision in the reduction sequence, but the trade-off is the production of a tool that is generally more effective in performance. Cowan (1999:594) notes that the increase in production effort, as well as the higher quality material and skillset required, causes curated technologies to not only be a more "expensive means of tool production," but also that the finished product is capable of being resharpened, repurposed or recycled. This quality gives curated technologies a longer use life and allows users to conserve raw material in situations of scarcity. Thus, in certain environments, curated tools confer the greatest "bang-for-your-buck" upon the tool user.

Another dimension to tool design has been discussed by Bleed (1986), who argues that curated technology can be classified in varying degrees of reliability and maintainability. Reliable tools are those that can be counted on to function properly the moment they are used. Maintainable tools are those whose failure can easily be remedied by a repair or alteration. Building on anthropological work done in the artic and Amazonia, Bleed (1986) was able to link predictability of resource availability and environmental setting to design considerations of this dimension. He found that maintainable tools were most prevalent in foraging strategies because of their ability to be adapted to the situation at hand, whereas reliable tools were more likely to be used where resource collection was dependent on a single, successful attempt.

Building on the nature of maintainable and reliable tools, Nelson (1991) argued that maintainable tools can be either flexible or versatile. A versatile tool is more generally shaped, and its versatility can be measured by the amount of different tasks it can perform. Versatile tools are more simple in design, but they're use requires more work time in the completion of a task. Flexible tools, on the other hand, are capable of being reshaped to suit a desired purpose. These tools begin in a generalized form and are then specialized when needed. Flexible tools, being adaptable, reduce the amount of time needed to complete a task. Both of these types offer different advantages in terms of efficiency. Versatile tools reduce the number of tools that must be carried, while flexible tools are more mechanically efficient. Nelson (1991) found that bifaces can be versatile, due to their generalized edge, or flexible if they are used to replace a hafting element with a specialized form, such as a spear foreshaft.

Kelly's (1988) study of the role of bifaces in mobile conditions demonstrates the flexibility of curated technologies. First, a biface can be an efficient core design when measured by its edge to weight ratio. Flakes produced from a bifacial core are comparatively thin and have more cutting surface than a flake from a unidirectional or bidirectional formalized core. This maximizes the tools carried and minimizes their weight. Second, the wider edge angle of a bifacial tool form lends it greater durability than a flake tool during heavy loading tasks, such as chopping. Lastly, bifacial tools may be shaped to fit an already existing haft, which are typically more time consuming to produce than the tools they seat. In this light, bifacial cores may represent a middle ground between expedient and curated technologies, allowing users to "have their stone and use it, too".

In experimental testing, Prasciunas (2007) examined the cutting edge to weight ratio of flakes produced from bifacial and amorphous cores. She concluded that, while bifacial cores produce more uniformly shaped and lighter flakes, the total usable cutting surface was not more than flakes produced from amorphous cores. In this light, it may be that other reasons, such as flake standardization or tool maintainability as discussed by Bleed (1986), were determining factors in whether mobile populations made use of bifacial tools.

The need for maximization of effort in tool production hinges on the scarcity of resources. Should a group be located at the source of a particular material, conservation pressure would be felt minimally. However, if located in an unknown territory or one lacking in a particular resource, conservation pressure on the group would understandably be higher. For the Pine Hills, high quality knappable material is located in gravel bars along streams and rivers in abundance, but the size of this raw material places an alternative element of scarcity upon its users in that there exists a breaking point in the feasibility of knapping activities. If only a flake is desired, initial size is of modest concern. But when a more formalized tool is needed, such as the many bifaces recovered in this region, cobbles of a minimum size are required. Therefore, it is reasonable to posit that the scarcity of resources played a significant role in the organization of technology for these tool producers.

Another question that bears asking is thus: if high quality material is available across the landscape, and expedient cutting edges require minimal effort to produce, what is to be made of the fact that bifacial tools, even rough and unformalized, occur with incredible frequency in the Pine Hills region? If maximization alone was the prime mover behind prehistoric knapping activities, would not unidirectional or bidirectional blade cores be more common? Such unfulfilled expectations indicate an alternative reasoning, and in keeping with the organization of technology approach, social and economic strategies must be considered as factors. If technology is designed to enhance the way in which social activities are produced or engaged in, it stands to reason that these activities can be inferred by examining tool remains. The key questions in such a case are: what are these social strategies, and in what way did their signature ripple through the organization of a particular technological system?

Debitage Analysis

Ahler (1989) has identified two theoretical principles that can be applied to all knapping activities and, therefore, debitage analysis. First, knapping is a reductive process, rather than an additive process. This distinction means that knapping activities are constrained by initial raw material size and form. Second, the variable application of load on an objective piece (the type of percussor used and the placement or angle of applied force) produces variations in the size and shape of the flake that is removed. This variation in load application is generally expressed by three types of fracture initiations (Cotterell and Kamminga 1987). Conchoidal fractures are those that produce pronounced bulbs of percussion, and are largely the result of hard hammer percussors (Cotterell and Kamminga 1987:686). Bending fractures are seen as resulting from soft hammer percussion (either hardwoods or antler/bone) as well as pressure flaking. These flakes have diffused bulbs of percussion and generally display some form of lipping on the platform (Cotterell and Kamminga 1979). Bipolar percussion, where an objective piece is placed on an anvil and struck with a hammer (either hard or soft), is known to produce compression fractures. The resulting flakes often display compression rings that originate from two opposing sides (Andrefsky 2005). While these features allow analysts to identify the type of load applicator used in the production of lithic debris, it has been noted that there is some overlap between the characteristics produced by hard and soft hammers, mainly due to the angle of the striking platform (Cotterell and Kamminga 1987:689).

There exist today three avenues of debitage attribute analysis that are used more widely amongst researchers: aggregate analysis, reduction stage typological analysis, and continuum-based approaches (Andrefsky 2005). These methods, utilizing various flake characteristics, are employed differentially depending on the research questions being asked. However, Binford (1978) and Bradbury and Carr (1995), among others, have argued for a multiple lines of analysis approach. This method confers greater inferential capability on the researcher and provides a more comprehensive understanding of both site formation processes and technological organization.

Aggregate analysis uses the size, shape and cortical features of complete assemblages as a means of accounting for variation in flake debris (Ahler 1989). In this type of analysis, flakes are passed through a series of nested screens. Flakes are then counted, weighed and measured for cortex coverage by excavated unit. Cortex bearing flakes are those which display cortex on the dorsal surface, platform or both. These flakes are generally considered to be removed early in the knapping process, and their presence is generally indicative of initial reduction of an objective piece (Ahler1989).

Stage reduction is a method of analysis that assigns individual flakes to discrete reduction stages in order to understand the types of tools produced in the formation of an assemblage. Magne (1985) used discriminant function analysis to define the variables best suited to stage assignment based on experimental reduction. His study concluded that four discrete reduction stages could be accurately identified in the archaeological record. Early stage flakes are those removed during core reduction. Middle stage flakes are produced in the shaping of specialized tools, while late stage flakes are produced by tool maintenance. The fourth type of reduction, biface thinning, is viewed as a special unit within the late stage category. These flakes were removed in the process of bifacial tool reduction, where the objective piece was thinned without significant removal of lateral surface area.

Magne (1985) identified two variables best suited to the assignment of flakes to stages. For platform remnant-bearing flakes, platform facet count was the best single feature. Flakes having zero to one facet were assigned to early stage, those with two facets were middle stage, and three or more facets belonging to late stage reduction. For all other flakes except shatter, dorsal scar count was similarly useful in stage assignment. Zero and one scars were indicative of early stage, two scars were indicative of middle stage, and three or more scars were indicative of late stage reduction. Biface thinning flakes were identified by three or more faceted platforms and the presence of lipping. Experimental reduction by Bradbury and Carr (1995) produced similar results as Magne's (1985). The strength of this methodology lies in its discrete classes of flake debris and its explicitly defined categories (Bradbury and Carr 1995).

A final approach to debitage analysis is the continuum-based approach. Shott (1996) and Bradbury and Carr (1999) argue that lithic reduction is best viewed as a continuum of activity. The placement of a flake's removal along this continuum is based on a regression formula, of which four have been developed (Bradbury and Carr 1999; Ingbar et al. 1989; Shott 1996). This continuum is represented as an ordinal scale ranging from zero (representing an initial core) to one (representing a completed tool). Continuum based approaches are beneficial in that they avoid potential researcher bias in the assignment of arbitrary stages, and they rely on metric attributes as diagnostic features. However, because of this, only platform bearing flakes can be used, which may introduce a different bias as flakes exhibiting crushed platforms (resulting from hard hammer percussion) will not be included in the analysis (Crabtree 1972:44). While these measurements can be time consuming to collect (Bradbury and Carr 2014), their utility means a continuum based analysis can be used as a check of other analytical methods.

In a recent publication, Bradbury and Carr (2014) attempted to further explore the continuum-based approach using statistical evaluation of non-metric flake attributes. The authors found that reliable predictions of a flake's placement along the production continuum were attainable by measuring attributes such as dorsal scars, platform facets, weight, and size grade. These attributes are similarly measured for in the previously discussed methods, and are much less time consuming than metric attributes. However, because this method relies on observer experience and accuracy rather than metric measurements, the potential for bias is increased. If this is kept in check, the authors show that non-metric attributes can offer accurate conclusions and can work in concert with other means of analysis.

One thing that should be called to attention regarding non-metric continuum-based analysis is the relationship of experimental replication and archaeological assemblages. In their article, Bradbury and Carr (2014) utilize experimental data in the analysis of a site whose tool stone is of the same type and quality as their experiments. This is beneficial in that materially-specific experimentation prevents potential error in applying these results to other material types, but it also limits its scope of application to a particular geographic region. The authors advocate for continued experimentation, which they say can help realize the aims of lithic analysts in understanding archaeological assemblages (Bradbury and Carr 2014:36).

In the course of personal communication, Andrew Bradbury has expressed continued difficulty using continuum analysis to interpret experimental assemblages of Citronelle gravel cherts. Alternatively, correspondence analysis is being explored as a new means of interpreting experimental knapping and archaeological data sets. Correspondence analysis (CA) is a multivariate statistical technique that is increasingly being utilized in archaeological analysis due to its ability to visually depict associations in categorical data. Because of the complexity in the mathematical principles of matrix algebra, a summary of the analysis is presented. More industrious researchers would be better served by reading Greenacre (1984)'s publication. This study is more focused on the practical applications.

In short, the first step in correspondence analysis is to assemble categorical data into a two-way contingency table where columns represent observational frequencies and rows represent the level of observation. Row and column totals (known as profiles) are created. Mass is then calculated for each row and column such that the sum of all table entries is equal to 1. Using these, a chi-square test may be performed to identify the presence of a statistically significant relationship between rows and columns. Multiple computer software programs exist that can visually plot this data onto a multi-dimensional subspace. The number of dimensions required to display all of the variance for table m x n is equal to m-1 or n-1, whichever is lesser. In this type of output, a scatterplot is produced that visually displays the variance between rows and the variance between columns. Distance on the graph between row data points can be measured as a visual display of similarity for their profiles. In the same way, the distance between column points can as well. Distances between column and row points, however, are not a direct relationship of similarity. Instead, row points can be interpreted based on their relationship relative to the graph defined by the column points, and vice versa, yielding general trends in the data. For the purposes of this study, all data were analyzed using the FactoMineR package within the R software program. This software carries the advantage of being open-source and also benefits from consistent and easy-to-find software updates available from multiple servers across the world. Lastly, it allows the user to manipulate the output so that the maximum amount of meaningful data is displayed.

Summary

The organization of technology approach to lithic analysis has advanced the ability of researchers to understand stone tool use patterns and their relation to other cultural systems. Multiple dimensions of technological organization have been identified that link settlement patterns, site formation, and economic strategies, all of which can be identified in the archaeological record. Accordingly, multiple means of debitage analysis exist, allowing analysts to tailor their methods to best answer the research questions being pursued. Finally, the increased use of statistical analysis has enriched the explanatory power of data gathered by established methods of analysis.

CHAPTER IV – EXPERIMENTAL DESIGN AND LABORATORY METHODS

This chapter provides a description of the framework and reasoning behind the flint knapping experiments included in this study, as well as a summary of the statistical and analytical methods used to interpret the experimental and archaeological assemblages. Special consideration is given to the experimental strategy, as it is the central interest of this thesis.

Replication Experimentation

Replication experimentation has been used in past lithic analyses to assess the accuracy of analytical methods. Andrefsky (2005:9) writes, "[C]ontrolled replication experiments produce a wide range of lithic artifact variability within differing parameters that can be controlled and understood." In speaking on the archaeological community's perception of value in replication experiments, the same author states,

> [L]ithic replication experiments gained new acceptance in the archaeological community as controlled scientific experiments that could provide important behavioral information to lithic analysis. The use of more controlled experiments in replication analysis has grown to include not only debitage studies, but also the analysis of finished lithic tools [Andrefsky 2005:9].

For this investigation, the general experimental design is patterned after Bradbury and Carr (1999), who expanded upon parameters set forth by Magne (1985). Citronelle gravel cobbles were collected from Camp Shelby Joint Forces Training Center in Forrest County, Mississippi. A portion of these cobbles were heat treated in an oven at a temperature of 287° C (550° F) for 48 hours. Fifty-two cobbles (40 heat-treated; 12 raw) were then selected based on size, shape, and material quality to be worked into bifacial tools.

Figure 3. Experimental Flintknapping

Note: All knapping was performed by the author.

Figure 4. Experimentally Knapped Bifacial Tools

Note: All cobbles were recovered from the Camp Shelby Joint Forces Training Center in Forrest County, Mississippi.

Figure 5. Tools Used in Flintknapping Experiments

Note: Clockwise, from the top left: Citronelle gravel hammerstone; Citronelle gravel hammer stone; Sandstone hammerstone; Leather hand pad; Whitetail (*Odocoileus virginianus*) antler billet; Whitetail *(Odocoileus virginianus)* antler tine.

Reduction proceeded in stages based on the desired end product. First, cobbles were reduced into a rough bifacial shape, with a working edge along all margins. When this was achieved, bifacial thinning was performed to thin the piece and reduce the overall mass. Lastly, the edges were straightened and a hafting element was notched into the base. With each hammer strike (herein referred to as an 'event'), all debris was hand manipulated through a 3.2 mm (1/8 in) screen. Any material retained in the screen was then numbered in the order of its removal. All knapping activities were performed by the author over a drop cloth so that any debris not captured in the screen could be collected at the end of the experiment. Freehand reduction technique was employed in all experiments, and the implement used for each event was recorded.

Because this study involves the use of local gravels, necessary adjustments were made to the experimental strategy that produced significant consequences for the resulting data. First, 3.2 mm screen was used in place of 6.4 mm. This was done in an effort to address the growing concern surrounding standardized recovery methods. For the Pine Hills area of Mississippi, standard recovery procedure dictates the use of 6.4 mm mesh screen. While this has been seen as sufficient in the past, a growing number of researchers argue that a significant amount of flake debris is smaller than this. Price (2012) has demonstrated quite effectively the capacity and ubiquity with which lithic assemblages can be misinterpreted as a result of standard field practices. In just one experimental study, 42 percent (n=563) of flakes produced in knapping Citronelle gravels were less than 6.4 mm in size (Price 2012:19). Therefore, 3.2 mm screen was used in order to explore the potential loss of meaning in excluding this material.

Second, the explicit definition of manufacture stages is essential for the interpretation of experimental results. The focus of this study is to examine the patterns in waste flakes that result from the manufacture of bifacial tools. The goal is to identify what non-metric attributes best identify the relative point at which a flake was detached. To this end, a categorical system of progressive stages was created against which these characteristics can be tested. The use of stages has been questioned by some as an imposition of modern techniques onto past mindsets (Bradbury and Carr 1999; Shott 1996). While this is no doubt a concern, it cannot be disputed that, given the same starting point and the same end point, a certain set of requirements must be met by all participants before that end is reached.

When examining this within the context of local Citronelle gravel cherts, certain stages can be segregated. First, because of the globular nature of some cobbles, the first requirement in the production of a bifacial tool would be the establishment of a cutting edge around the objective piece. Second, mass must be removed from the interior of the cobble so that two faces are produced and thinned. Third, the edges must be retouched so as not to be too sinuous. In following this recipe, alterations in knapping tools or knapping objectives can be used to distinguish stages. Therefore, the first stage is defined by the goal of establishing a bifacial edge using hard or soft hammer direct percussion, as necessary. The second stage is bifacial thinning, where hard or soft hammer direct percussion was used to thin the interior mass of each face. This results in a more bifacial overall shape and facilitates an easier insertion into a haft. The third stage encompasses the straightening of the working edge and the definition of a hafting element. This last stage is performed using pressure flaking as the edge by this point is too acute to accept the force of direct percussion. By defining stages in terms of implement of detachment and intended goal, it can be reasonably asserted that indigenous stone tool producers similarly conceived of such a progression.

Lithic Debitage

As previously detailed, approaches in debitage analysis are as varied as the questions they seek to answer. Overall, their aim is to better understand the variability in lithic by-products that results from the interplay between a socio-economic system and the environment. For the purposes of this study, multiple attributes were recorded based on work by Bradbury and Carr (1995), who used work presented by Magne (1985) in the formation of their system. This method has also seen widespread use in the Pine Hills region, providing continuity in data collection that allows for inter-site comparisons. For this same reason, all experimental materials were coded in the same manner. Descriptions of the coded attributes are presented below.

Size Grade

All pieces were passed through a series of nested sieves. Flakes captured within each sieve were coded as being within the following respective ranges: (1) >25.4 mm, (2) 25.4-12.7 mm, (3) 12.7-6.4 mm, (4) 6.4-3.2 mm, (5) <3.2 mm. In all cases, pieces were hand-manipulated through each sieve. Size grade has been interpreted as reflective of the stage at which a flake was detached. It has been posited that, for example, the recovery of predominantly small size grades at an archaeological site is indicative of an emphasis on the final stages of tool manufacture or maintenance (Ahler 1989; Jackson and Fields 2000).

Mass

The mass (sometimes reported as weight) of all pieces was recorded in grams to the nearest .01 g. Similar to size grade, mass has been implicated as a sign of specific reduction activities. The concentration of pieces within a specific range of mass may be a sign of a restricted reduction techniques or activities at a site. It is also thought that mass may help identify the initial mass of nodules or cobbles prior to being worked (Jackson and Fields 2000).

Raw Material

The high frequency at which Citronelle gravel cherts can be found in the Pine Hills region has manifested itself in the archaeological record in the form of widespread and frequent recovery of projectile point/knives and debitage remains. As such, it is of primary concern in this study. The recovery of other, sometimes non-local, material is not uncommon and was coded for as well. Categories included in the experimental assemblage were Citronelle gravel chert and Heat-treated Citronelle gravel chert. Other material categories include: Tallahatta sandstone (sometimes called Tallahatta quartzite), Quartzite gravel, Sandstone, Agate, and Petrified wood.

Portion

The portion of each piece of debitage was recorded as one of the following categories: complete flake, proximal, medial, distal, split longitudinally, thermal spalls and non-orientable debris. Flakes are considered complete if they retain an identifiable platform, bulb of percussion, marginal edges and some form of termination (feathered, stepped, hinged or overshot). Proximal fragments include pieces with the platform or bulb of percussion but no termination. Medial fragments contain identifiable lateral margins but lack a platform or termination. Distal fragments retain the flake's termination but do not have a platform or bulb of percussion (Andrefsky 2005). Flakes that are split longitudinally have been fractured perpendicularly to its striking platform. Thermals spalls result from the process of excessive thermal alteration. Pieces in this category can be identified by damage such as "crazing". Non-orientable debris includes pieces that are blocky, angular chunks with no clear attributes typical of chipped stone debris (Bradbury and Carr 1995). For the purpose of this experiment, no effort will be made to rejoin flakes from the experimental assemblage as it has been shown that such a task is unlikely for archaeological assemblages (Ingbar et al. 1989:126).

Platform

Platform characteristics have been thought to carry meaningful insight into the manufacture process of stone tools. Bradbury and Carr (1995) found that it was indicative of reduction stage. Categories include: cortical-nonlipped, cortical-lipped, noncortical-nonlipped, noncortical-lipped, and incomplete. The incomplete category included pieces that were either partially missing or missing altogether.

Platform Facet Count

The number of facets present on a flake has been widely seen as an indicator of the stage in which it was removed. The more platform facets present, the later in the manufacturing process it was removed. Facets were recorded in ordinals up to five. Flakes with more than five facets were recorded in the same group.

Cortex

Although once thought to be indicative of reduction stage, cortex has been shown to hold marginal value in determining a production sequence. It is nonetheless recorded, as its presence or absence may be indicative of other phenomena and it is quickly accomplished. Percent of dorsal cortex was coded in the following categories: 0%, 1-25%, 26-50%, 51-75%, 76-99% and 100%.

Dorsal Scar Count

Similar to platform facets, dorsal scars have been seen as an indicator of reduction stage. Flakes with more dorsal scars are thought to be produced later in the reduction sequence. Dorsal scars were coded in ordinals up to five, and flakes with higher counts were coded as one category. Flakes that could not be determined due to material impurities were coded as indiscernible.

Modification

Although flakes are produced in the manufacture of other tools, many indigenous groups have made widespread use of flakes as tools. In some instances, modification of flake byproducts produced a sufficient tool for a given task. In other instances, modification of a flake tool occurred as a result of its use. Categories include none obvious, retouched-one edge, retouched-two edges, utilization damage-possible, and utilization damage-obvious.

Reduction Type

Reduction type is assigned based on the presence of a suite of attributes. Reduction types include: bipolar, bifacial thinning, notching, standard, edge retouch/straightening, and grinding. The assignment of reduction types can illuminate several aspects of the overall nature of reduction that occurred at a site. Bipolar flakes are those that exhibit bulbs of percussion on opposing ends. Notching flakes are thought to be shorter, more fanned out and relatively small. Bifacial thinning flakes are thought to have been removed in an effort to remove interior mass from the face of a biface. Edge retouch or straightening flakes are produced by pressure flaking. They tend to be smaller, thinner, and have few flake scars on their dorsal surface. Grinding is a process by which knappers prepare an edge to accept the force of a flaking tool. It is typically thought of as a sign of increased effort and care in the manufacture process. These pieces can be very small, and sometimes may include blocky fragments or shatter. The experimental assemblage was coded based on the knapper's intent and the flaking style employed for each event. The archaeological assemblages examined in this study were coded based on the suite of characteristics retained on the piece. If no determination could be made, it was coded in the standard category.

Statistical Analysis

After the flakes were coded, they were assembled into a two-way contingency table and input into R software program. Using the FactoMineR package, a correspondence analysis was conducted, allowing each attribute to be examined individually and together. Using this method, the attributes most predictive of stage or position of removal could be explored in concert and individually for their explanatory power.

CHAPTER V – RESULTS

This chapter presents the results of the knapping experiments and statistical analysis. This includes examination of the nonmetric flake attributes, both as a whole and individually. Using these results, a process for the segregation of flakes into discrete stages is applied to the experimental assemblage. Following this, the same process is applied to archaeological data from the Pine Hills region as a test of its utility in interpreting site activities, site functions, and implications for mobility strategies of past local inhabitants.

Experimental Knapping Results

Of the 52 cobbles selected for reduction, 13 were abandoned due to poor material quality. Twelve cobbles were rendered unworkable due to interior seams or fractures, making controlled flaking too unpredictable. Another six cobbles were fractured during knapping into fragments that were blocky or unworkable. These 31 experiments were deemed production failures. For the remaining experiments, four cobbles were split into two or more workable pieces and were set aside. Eleven were halted due to their odd shape but were of good quality material and could be worked down further in the future. The final six experiments were successfully knapped into bifacial tools. Five of these were of heat treated material. Because of its widespread practice amongst prehistoric people, only the analysis of these five bifacial experiments is included. Table 1 displays the metric data for each experiment before and after knapping took place.

Table 1

Metric Cobble Dimensions Before and After Knapping

Experiment	Reduction Method	Initial Mass (g)	Final Mass (g)	Initial Length x Width (mm)	Final Length x Width (mm)	Initial Thickness (mm)	Final Thickness (mm)
4	HH/SH/P	94.1	19.2	68 x 39.5	47.5 x 30	28	10.5
13	HH/SH/P	241.2	30.74	92 x 63.5	68 x 36.5	33	13
18	HH/SH/P	194.8	84.1	73.5 x 59	72 x 49	38	19.5
30	HH/SH/P	91.2	19.1	75.5 x 35.5	61.5 x 23	20	13
33	HH/SH/P	133.6	46	79 x 44.5	70 x 35	28	18

Note: HH = Hard Hammer, SH = Soft Hammer, P = Pressure flaking.

In total, 1164 pieces of debitage were captured by a 3.2 mm screen in the five experiments under examination. As displayed in Table 2, a total of 611 flakes retained an intact platform. One observation of note here is the relatively low occurrence of middle stage flakes in three of the five experiments (see Chapter IV). Middle stage flakes make up 11.78 percent (n=72) of all platform bearing flakes, but can occur as little as 0 percent (Experiment 30) and as much as 25.52 percent (Experiment 18). Such variation and low occurrence indicates potential difficulty in distinguishing this stage from early stage flakes.

Table 3 provides a summary of the distribution of platform bearing flakes by size grade category. The majority of flakes produced in the reduction continuum fall into the 3.2 mm size grade. This reinforces the previously identified concerns with standardized recovery procedures in the Pine Hills Region, in that 71.03 percent (n=434) of the flakes produced in the course of this study would not be recovered. Only three platform bearing flakes were larger than 25.4 mm. Each of these is of sufficient size to be worked into another tool (eg, drill, scraper, burin, projectile point/knife) or be used as an expedient tool with minimal shaping.

Table 2

Platform Bearing Flakes by Reduction Stage

Experiment	Flakes with Complete Platform	Stage 1	Stage 2	Stage 3
4	93	29	4	60
13	107	74	1	32
18	192	41	49	102
30	117	14	0	103
33	102	33	18	51
Totals	611	191	72	348
%	100	31.26	11.78	56.96

Table 3

Platform Bearing Flakes by Size Grade

Experiment	Size Grade				Totals
	1 >25.4 mm	2 25.4-12.7 mm	3 12.7-6.4 mm	4 6.4-3.2 mm	
4	1	7	15	70	93
13	1	16	44	46	107
18	0	18	33	141	192
30	1	4	10	102	117
33	0	9	18	75	102
Totals	3	54	120	434	611
%	.50	8.83	19.64	71.03	100

To examine patterns in flake attributes across stages, a correspondence analysis was performed. This exploratory technique allows categorical variables to be plotted in a multidimensional subspace that visually displays patterns in large data tables. Figure 6 displays the correspondence analysis output scatterplot of aggregate attribute data based on stage of removal for all five bifaces. The reduction stages are represented in red, while the flake attributes are represented in blue. It should be reiterated that distances between reduction stage points and flake attribute points are not meaningful. Rather, their locations reflect general trends or tendencies within the data.

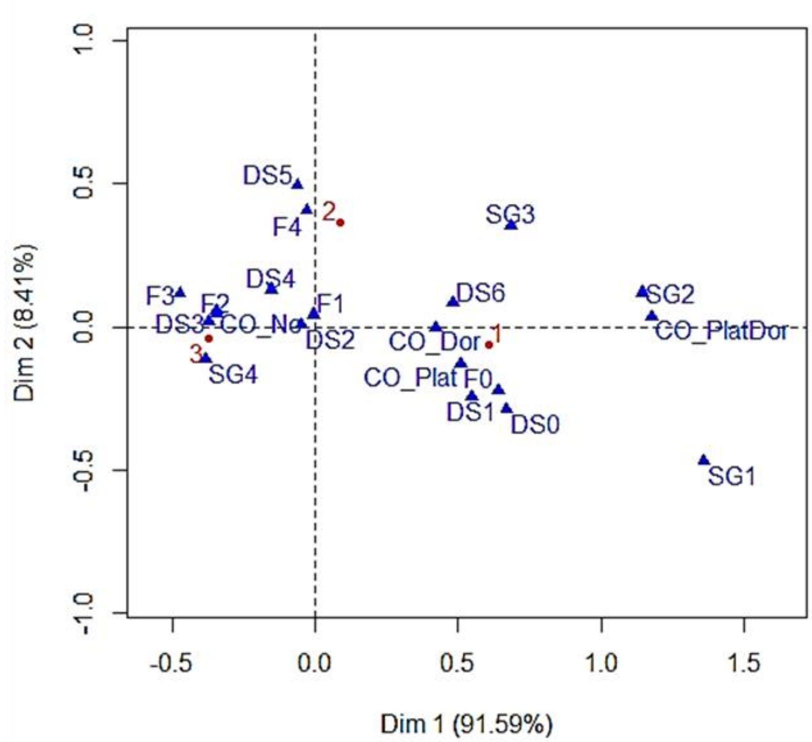

Figure 6. Correspondence Analysis of Reduction Stage by Aggregate Attribute Data

Note: $\chi 2$ (df=38, n=611) = 541.52, p-value < .001. See Appendix for eigenvalue report. Stages of reduction are represented in red; flake attributes are represented in blue.

From this scatterplot, multiple things can be noticed. First, all of the inertia is displayed in the first two dimensions. The x-axis, here, is defined by 89.14 percent of the inertia. In looking at the data from this perspective, there is a strong polarization between the early and late stage categories from right to left. Early and late stage categories lie close to and define the x-axis. The y-axis is defined by the middle stage category, indicating that it differs somewhat from both early and late stage flakes. However, this may be a weak distinction as this axis accounts for 10.86 percent of the total inertia. Sample size may be a factor in this outcome, but its separation is meaningful to some degree. Second, the arrangement of the attribute data shows clustering among the size grade, facet count, dorsal scar count, and cortex coverage categories within the stage-defined space. To examine this more closely, each category can be segregated and computed by stage independently.

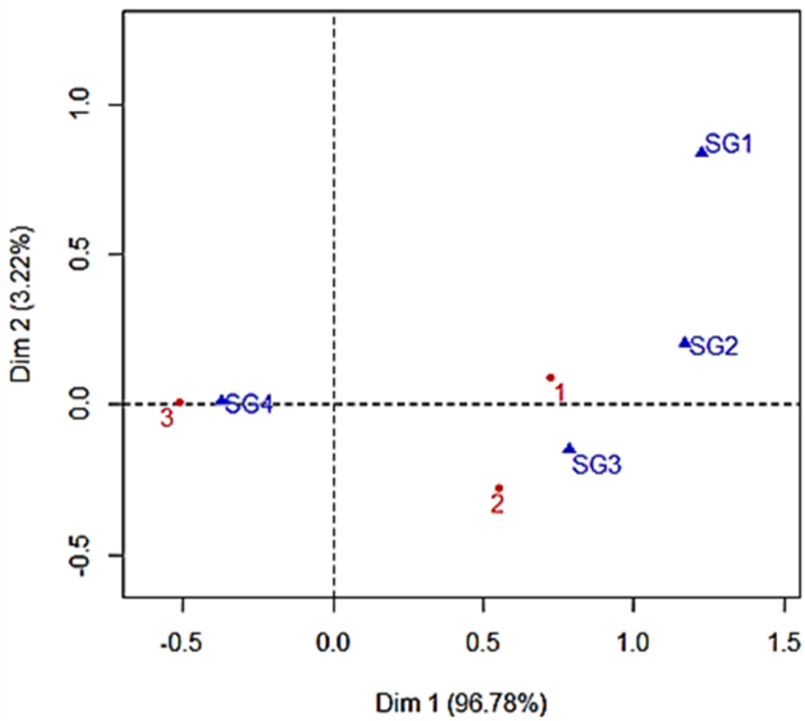

Figure 7. Correspondence Analysis of Reduction Stage by Size Grade

Note: Stages of reduction are represented in red; size grades are represented in blue.

When reduction stages are examined by size grade (Figure 7), early and middle stages are strongly separated from late stage along the x-axis, which describes 96.78 percent of the inertia. The 25.4 mm (SG1), 12.7 mm (SG2), and 6.4 mm (SG3) size grade categories are plotted in the area of the former, while the 3.2 mm (SG4) size grade category is plotted in the area of the latter. This makes intuitive sense because of the definition of stages by hammer type. Both hard hammer and soft hammer direct percussion require the use of tools with larger striking surfaces that generate greater applied forces on the objective piece. Greater forces and larger platforms produce larger flakes. While the y-axis only explains 3.22 percent of the inertia, it none the less yields some distinction between the early and middle stages. The former shows a much stronger association with categories 25.4 mm and 12.7 mm, while size grade 6.4 mm shows some association with both. The low percentage of inertia explained by this dimension cautions against any firm distinctions, but may indicate a trend of reducing flake size in the course of knapping bifacial tools.

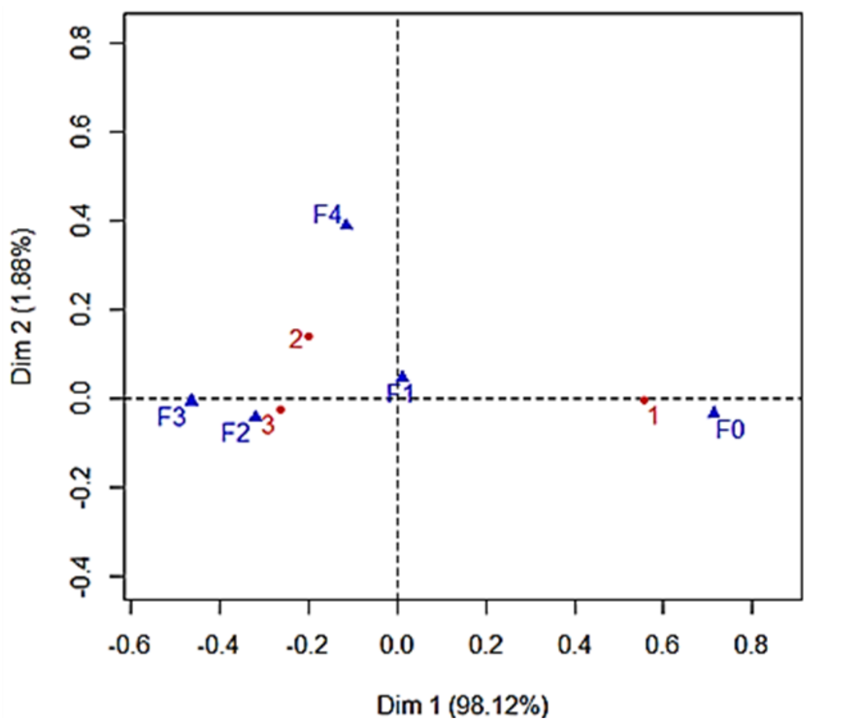

Figure 8. Correspondence Analysis of Reduction Stage by Facet Count

Note: Stages of reduction are represented in red; facet count categories are represented in blue.

When examined according to platform facets (Figure 8), the vast majority (98.12 percent) of the inertia can again be explained by the x-axis. However, unlike size grade, the greatest distinction in this case exists between early stage and middle/late stage flakes. Flakes with zero (F0) facets are plotted nearest early stage reduction, and flakes with two (F2) or three (F3) facets lie nearer to late stage reduction. Flakes with zero facets, being either flat or cortical, would be naturally associated with the earliest stage, before flake scars can accumulate on the striking edge. Flakes with two or three platform facets are strongly associated with later stage reduction likely due to their overall size. Although they are removed at a time when previous flake removals are most present on a biface, their smaller platform size will restrict the amount of previous removals evidenced on the platform. Flakes with four facets (F4) are strongly differentiated from the rest along the y-axis, and lie closest to the middle stage category, in contrast to previous experiments (Bradbury and Carr 1995; Magne 1989). But, because the y-axis is defined by 1.88 percent of the total inertia, the strength of this association is suspect. It is most likely the result of larger hammer size capturing evidence of more flake removals on middle stage platforms. Flakes with one (F1) facet are plotted at the center of the graph, meaning that they have low inertia. This would suggest that flakes with one platform facet occur at equal rates in each stage.

Figure 9 displays the relationship between reduction stage and dorsal scar count. Like facet count, early stage is differentiated from middle and late stage along the x-axis. Flakes with zero (DS0) or one (DS1) dorsal scars are located in the area of early stage reduction. The two scar category (DS2) lie roughly in the area of late stage reduction, but its close proximity to the center reflects very low inertia, and therefore little meaning when examined alone. Flakes with three (DS3) and four (DS4) scars lie in the area of middle and late stage reduction. Flakes with five scars (DS5) are separated from the main axis and lie in the area of middle stage reduction, while flakes with six or more scars (DS6) associate with early stage reduction. The association of five scars with middle stage reduction is what primarily defines the y-axis (representing 9.11 percent of the total inertia).

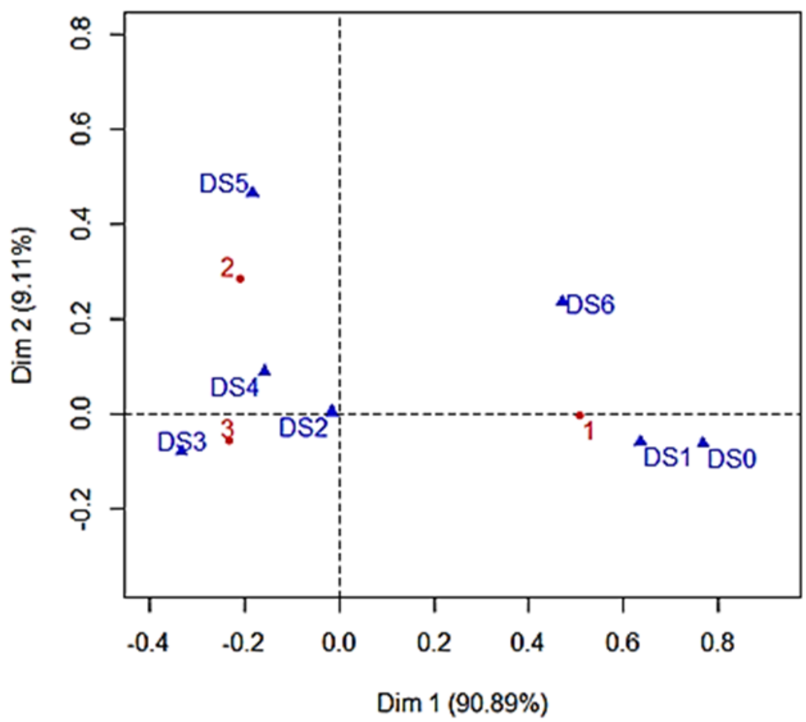

Figure 9. Correspondence Analysis of Reduction Stage by Dorsal Scar Count

Note: Stages of reduction are represented in red; dorsal scar categories are represented in blue.

When viewed through the x-axis, middle stage reduction lies closer to late stage reduction. This pattern both follows and differs from that reported by Magne (1989) and Bradbury and Carr (1995), who noted that flakes with zero or one scar were removed in the early stage, flakes with two scars were removed in the middle stage, and flakes with three or more dorsal scars were removed in the late stage category. The location of the zero and one scar categories in the area defined by early stage reduction is intuitive as there is less opportunity for flake removals to be captured on the dorsal surface of detached pieces. The location of the two, three, and four dorsal scar categories in the area of middle and late stage reduction would seem similarly intuitive for inverse reasons. These flakes would be removed at a time when more flake scars can be captured on a dorsal surface. The location of the five dorsal scar category in the area of middle stage reduction is attributed to the size of middle stage flakes. These will be larger than late stage flakes and will therefore display more evidence of previous flake removals. A similar reasoning is behind the association of six or more dorsal scars with early stage reduction.

The locations of the five dorsal scar and six or more dorsal scar categories are unique and deserve more attention. While early stage reduction may produce comparatively more flakes with zero or one scar, as many as six can occur. This is likely a consequence of raw material shape and size. Because of the small size and sometimes odd shapes of Citronelle gravel cherts, significant shaping and thinning were accomplished in the earliest reduction stage before available length and width are exhausted beyond recovery. In contrast with larger, quarried objective pieces, sufficient width was not available so as to allow for well-represented dedicated thinning stages, nor does it appear to be necessary. Instead, bifacial shaping and thinning must occur at the same time. This explanation is reinforced by the relatively low occurrence of bifacial thinning flakes (Table 2). While isolation of the inertia determined by flake scars is useful in understanding it’s variation across reduction stages, it appears most informative to examine a suite of traits to define reduction stages.

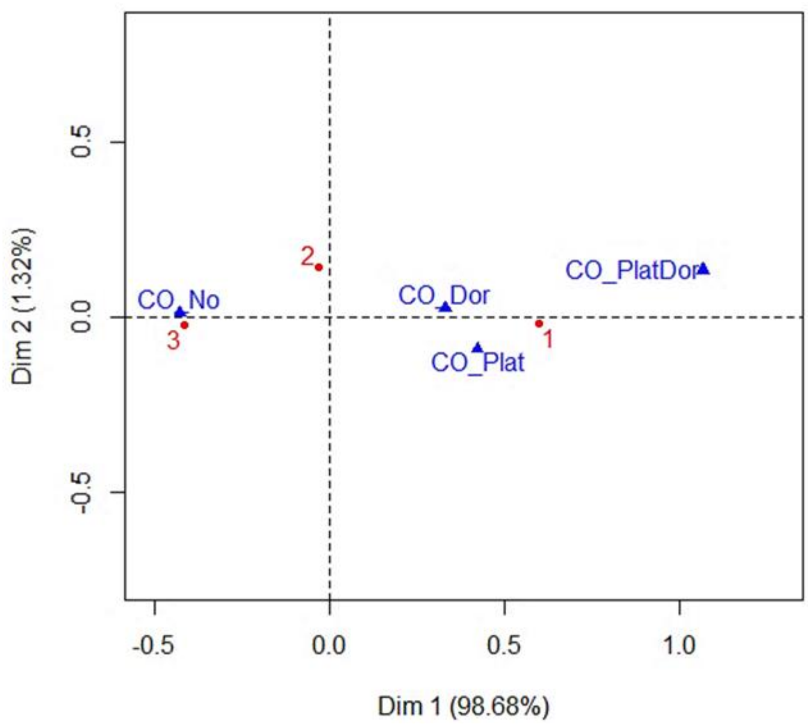

Figure 10. Correspondence Analysis of Reduction Stage by Cortex Coverage

Note: Stages of reduction are represented in red; cortical categories are represented in blue.

The reliability of cortex coverage has been considered with a large degree of skepticism among lithic analysts for several decades. However, its presence or absence is easily recorded and takes minimal time. In these five bifacial reduction experiments, the presence or absence (CO_No) of cortex was recorded for the platform (CO_Plat), dorsal surface (CO_Dor), and both together (CO_PlatDor). Figure 10 plots the correspondence analysis output of this data in relation to reduction stage. Along the x-axis (which explains 98.68 percent of the inertia) a distinct pattern can be observed where flakes with cortex on any portion of its surface are plotted to the right of the axis' center, near early and middle stage reduction. These can be contrasted with flakes retaining no cortex, which are plotted to the left of the axis' center, near late stage reduction. This is likely a product of stage definition. It should be noted that middle stage reduction, is plotted near the center of the x-axis, indicating an equal probability for these flakes to retain portions of cortex.

To summarize the correspondence analysis, trends in flake attributes can be seen across the progression of reduction stages, but clear distinctions between stages based on a single attribute is not readily apparent. Instead, the correspondence analysis output suggests that a suite of traits may be used to process Citronelle gravel debitage. The data suggest that size grade is the best attribute to discriminate late stage flakes from early and middle stage flakes. However, despite the strong association with late stage reduction, 3.2 mm flakes are produced throughout the knapping process. This can be due to the strike of the hard hammer producing smaller flakes alongside the intended flake or the use of hammerstones to grind or prepare the edge for further reduction. Next, dorsal scars and platform facets suggest equally strong ability to segregate early stage from late or middle stage flakes. These two attributes have been well documented as having descriptive utility in debitage analysis, and the data presented here only add to it. Further, these attributes are recorded relatively easily. As such, it is the combination of these three attributes that may be best employed to sort Citronelle gravel debitage.

Cross-Validation of Correspondence Analysis

Using the attributes that were highlighted by correspondence analysis, to what degree can bifacial tool production be identified? To test this, a cross-validation test was performed that attempts to assign individual flakes to reduction stages. The first step was to separate all platform bearing flakes. Second, platform bearing flakes were separated by size grade. Flakes retained by the 25.4 mm, 12.7 mm, and 6.4 mm screens were grouped into the early/middle stage. Flakes retained in the 3.2 mm screen were then sorted by flake scars and platform facets. Those with two or three platform facets and two or more dorsal scars were categorized into the late stage category. The results of the cross-validation test can be seen in Table 4.

Table 4

Cross-Validation Summary of Stage Assignment

Experiment	Early/Middle Stage		Late Stage		Total	Total
	Predicted	Actual	Predicted	Actual	Predicted	Actual
4	23	21 (91.3%)	26	25 (96.1%)	49	46 (93.8%)
13	61	54 (88.5%)	14	12 (85.7%)	75	66 (88.0%)
18	51	47 (92.1%)	66	59 (89.4%)	117	106 (90.6%)
30	15	13 (86.6%)	26	25 (96.1%)	40	38 (95.0%)
33	27	22 (81.4%)	23	22 (95.6%)	50	44 (88.0%)
Totals	177	157 (88.7%)	155	143 (92.3%)	331	300 (90.6%)

Note: Percentages reflect accuracy rate of stage assignment.

In total, 54.2 percent (n=331) of the 611 platform bearing flakes were assigned to a reduction stage with an overall accuracy of 90.6 percent (n=300). This method represents a more parsimonious attempt at stage based classification, but carries a not unsubstantial rate of predictability. In the case of each experiment, both identifiable stages were marginally overestimated. This is a result of the variability in flake attributes across the reduction continuum. The inability to sort a larger portion of platform bearing flakes into a reduction stage is due to the fact that 3.2 mm sized flakes are produced with regularity throughout the biface production continuum. Because of the high quality of heated Citronelle gravel chert, striking platforms can become brittle and may require regular stiffening to accept the next strike. In the experiments presented here, this was accomplished by using the available hammerstones to grind the platform. Stiffening or grinding of the platform often produced small flakes that were trapped and recorded as an event. These might otherwise be disregarded as shatter, yet when viewed under a microscope, can look similar to a retouch or edge-straightening flake. Therefore, 3.2 mm flakes with zero or one platform and zero or one flake scars are not indicative of a reduction stage.

Another area of difficulty is the ability to distinguish middle stage flakes from early stage flakes. As mentioned earlier, a relatively low amount of middle stage flakes were produced in the experimental knapping. Moreover, the amount of middle stage flakes in each experiment was highly variable. An attempt was made to separate these using platform facet count, as the correspondence analysis output indicates this attribute is the strongest discriminator between the first two stages. Accordingly, early stage flakes were defined by zero or one facet, while middle stage flakes were defined by two or more facets. Only flakes sorted in the early/middle stage category from Table 4 were included.

Table 5

Cross-Validation Summary of Early and Middle Stage Assignment

Experiment	Early Stage		Middle Stage		Total	Total
	Predicted	Actual	Predicted	Actual	Predicted	Actual
4	18	14 (77.7%)	5	1 (20.0%)	23	15 (65.2%)
13	39	38 (97.4%)	22	1 (4.5%)	61	39 (63.9%)
18	26	16 (61.5%)	25	18 (72.0%)	59	34 (57.6%)
30	10	9 (90.0%)	5	0 (0%)	15	9 (60.0%)
33	19	11 (57.9%)	8	4 (50.0%)	27	15 (55.6%)
Totals	112	88 (78.6%)	65	24 (36.9%)	177	112 (63.3%)

Note: Percentages reflect accuracy rate of stage assignment.

Table 5 displays the cross-validation summary of early and middle stage platform-bearing flakes. For the 177 flakes that were predicted, 63.3 percent (n=112) were accurately assigned to either stage. In some cases, such as experiments 4, 13 and 30, classification of early stage flakes was above 70 percent correct, but that of middle stage flakes was 20 percent or less. Only in one experiment (18) was middle stage assignment better than 50 percent correct. Experiment 30 was unable to properly identify middle stage flakes because no middle stage reduction took place, yet five early stage flakes were sorted into this category. As mentioned earlier, the overall representation of middle stage reduction in the experimental assemblage is small, which makes recognizing attribute patterns difficult. Because of the substantial thinning that must take place in the early stages of producing a biface, the continuity of attributes is such that accurate predictions are hit-or-miss. Instead, it appears more productive to examine the first two stages together.

Putting the Experimental Data to Work

The experimental data indicate the ability to identify two distinct stages of bifacial tool manufacture. The first is core reduction and bifacial shaping, which corresponds to early and middle stage flaking. In this stage, a core is reduced to the point that a bifacial edge is established around the edge and the interior mass of each face is reduced. The second identifiable stage of manufacture is tool formalization and maintenance. This represents late stage flaking, and involves the formation of a hafting element and the straightening or shaping of lateral and distal margins. To examine this categorical system in application, the stage assignment method outlined above was used to categorize debitage from three archaeological sites within the Pine Hills region of southeastern Mississippi (Table 7).

Table 6

Prior Reduction Stage Assignment for Local Sites

Site	Early	Middle	Late
22FO1515	46.11%	32.33%	21.55%
22FO1545	61.7%	22.34%	15.96%
22FO1546	47.6%	24.8%	27.6%

Note: Reduction stage data reported by Jackson (2012). Stage data reflect the percent of total per site. Method of analysis based on Bradbury and Carr (1995).

Table 7

Experimentally-Based Reduction Stage Profile for Local Sites

Site	Flakes with Complete Platform	Early/Middle Stage	Late Stage	Total Assigned
22FO1515	1632	835 (75.1%)	277 (24.9%)	1112
22FO1545	63	61 (98.4%)	1 (1.6%)	62
22FO1546	593	378 (82.4%)	81 (17.6%)	459

Note: Percentages reflect proportion of total platform bearing flakes.

The first site under analysis is 22FO1515. Originally examined by Jackson (2012), the sampled Citronelle gravel debitage (n=3852) was found to be composed mostly of early stage reduction (Table 6), with middle and late stage reduction represented to progressively lesser extents (Jackson 2012). The large amount of core reduction, in conjunction with the variety of stone tools recovered and baked clay features, indicated a residential site function (Jackson 2012:121-122). But in order to examine its relationship with the experimental data in the present research, the dataset was revisited. A total of 1632 proximal or whole flakes were subjected to analysis using the methods derived from the Citronelle gravel replication experiments. Based on these methods, 1112 flakes could be sorted into a reduction stage. Of these, 835 (75.1 percent) fall into the early/middle stage category, while 277 flakes (24.9 percent) are categorized as late stage reduction. A total of 520 flakes (representing 31.9 percent of all platform bearing flakes) were unable to be assigned to a reduction stage category. According to this method, overwhelmingly, core reduction comprises the majority of stage representation, whereas tool formalization and maintenance represents roughly one quarter of the segregated flakes. This stage profile is very similar to that reported by Jackson (2012) despite the ability to distinguish middle and early stage reduction. Because both methods arrived at a similar result, the debitage attribute data from 22FO1515 strongly suggests that prehistoric site activities were residential in nature. The significant amount of flaked or tested cobbles are evidence that raw tool stone was likely collected and brought to the site for further reduction. Cobbles were heated treated and knapped, producing a large amount of flake tools useful in a variety of residential tasks. The experimental data indicates roughly equal proportions of early/middle to late stage flakes in the production of formal hafted bifaces. The low incidence of late stage or maintenance flakes indicates that some tool formalization or specialization did occur over the course of occupation, but that it was limited in scale and that the tools were maintained elsewhere. Additionally, the presence of unfinished and abandoned bifaces may account for some of the early/middle stage flake representation.

Alternatively, because a sample of the debitage was subjected to attribute analysis, it is possible that 22FO1515 had multiple activity zones for discrete cobble reduction trajectories. The sample used for analysis primarily consisted of material recovered in or around Feature 2, which was uncovered in the only 2-x-2 meter unit excavated during Phase II recovery. This unit was the most productive of the site, yielding three formalized hafted bifaces, one distal end of a formalized biface, ten unfinished bifaces, five cores, one modified flake, and copious amounts of debitage. It may be the case that the results of the debitage attribute analysis are characteristic of the particular reduction activities of this area of the site, while tool specialization or maintenance occurred elsewhere. Because this site was excavated using 3.2 mm screens, it is unlikely that this sized material was allowed to slip through the recovery process.

The second site under analysis is 22FO1546. Similar to 22FO1515, it was found to be characterized mostly by early stage reduction (Table 6), with middle and late stage reduction also represented (Jackson 2012). Of the 1045 total pieces of Citronelle gravel debitage in the assemblage, 593 retained a complete platform and were selected for reanalysis. According to Table 7, 368 flakes (82.4 percent) were sorted into the early/middle stage category. Only 81 flakes (17.6 percent) can be classified as late stage reduction, while 144 flakes (24.3 percent of all platform bearing flakes) were unable to be assigned. Based on this analysis, the reduction stage profiles at 22FO1546 mirror those reported by the previous methods. This supports the conclusion that the function of 22FO1546 was residential in nature. But, while these conclusions are similar, the relative proportions of stage representation are not (see Tables 6 and 7 for comparison). The late stage representation is approximately half of that originally reported, and the early and middle stages are better represented. This is likely the result of the amount of unclassifiable material using the methods presented in the present research.

The last site under comparison is 22FO1545. Unlike the previous two sites, this one was subjected to a surface collection recovery due to the extent of surface erosion. As a result, only 100 pieces of Citronelle gravel debitage were recovered. The reduction stage classification as reported by Jackson (2012) can be seen in Table 6. Of these pieces, 63 flakes with a complete platform were reanalyzed based on the experimental data. Almost all of these (n=61, 98.4 percent) are reclassified as early/middle stage reduction. while late stage reduction was represented by one flake (1.6 percent). Only one flake could not be assigned. These findings conflict with the original analysis, primarily due to the role of size grade in segregating reduction stages. Because surface collection was used to recover cultural materials in the field, almost no 3.2 mm flakes were recovered, and therefore, very little late stage reduction is reflected in the data. As a result, it is difficult to characterize with certainty the nature of reduction activities at this site. Instead, it is clearer to say that the use of 3.2 mm screens in recovery can produce much more holistic representation of past activities.

In reanalyzing these three Pine Hills archaeological sites, a pattern of core reduction and tool shaping is characteristic with varying degrees of representation at each locale. In following the multiple lines of reasoning approach, these results were checked by feeding the original datasets into the FactoMineR package in the R statistical environment. Sums of each non-metric category were assembled, and a correspondence analysis was performed in the same manner as before. Figure 11 displays the output scatterplot that includes the archaeological datasets. In this graph, the space is defined by the experimental dataset alone, while the archaeological data are represented as supplementary points (in brown). This prevents the archaeological data from skewing the results, and allows the experimental data to facilitate analysis of the former. For these purposes, it is best to interpret the archaeological data in space as defined by the reduction stage data.

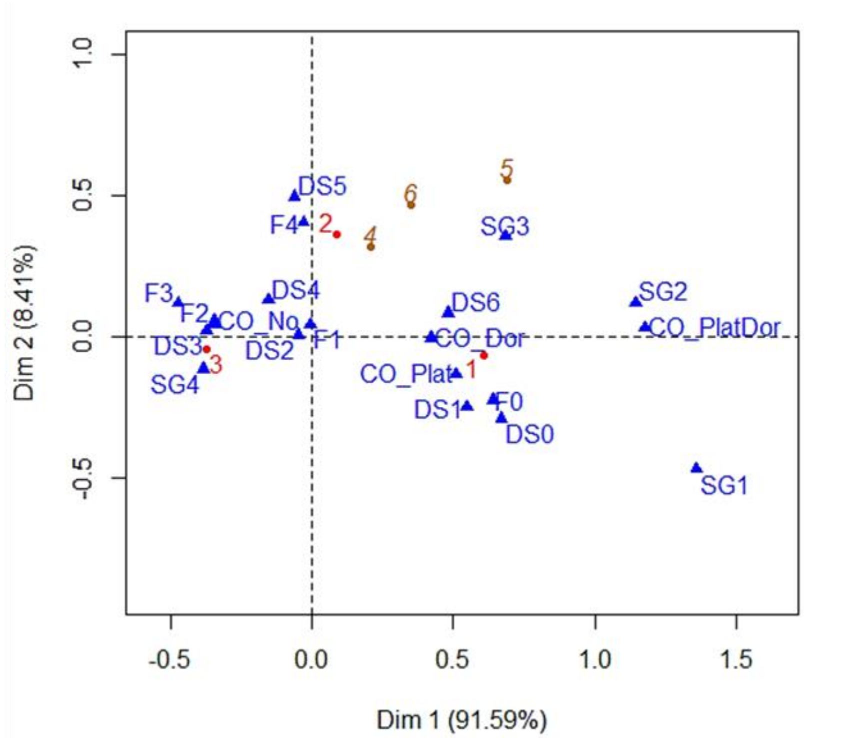

Figure 11. Correspondence Analysis of Experimental and Archaeological Data

Note: Data points in red (1, 2, and 3) represent the stages of reduction in the experimental dataset. Data points in brown (4, 5, and 6) represent the archaeological sites under comparison (22FO1515, 22FO1545, and 22FO1546 respectively). Data points in blue represent previously discussed flake attributes.

The scatterplot output (Figure 11) clearly shows that all three archaeological sites fall to the right of center along the x-axis, which like Figure 6, defines 91.59 percent of the total inertia. Data points 4 (22FO1515) and 6 (22FO1546) lie in the space between early and middle stage reduction. Data point 5 (22FO1545) lies slightly to the right of early stage reduction. In the case of each, the patterns identified via the reduction stage reanalysis are similarly reflected in the correspondence analysis. The proximity of sites 22FO1515 and 22FO1546 to middle stage reduction (represented as the red 2 data point in Figure 11) shows that, while early/middle stage reduction is most characteristic of past reduction activities, the middle stage constitutes a significant proportion of this material. In other words, bifacial preform shaping was likely a part of the technological organization of the prehistoric inhabitants of these sites.

Summary

The results of the biface knapping experiments indicate that the interpretation of Citronelle gravel debitage is distinct from other forms of raw material. The low occurrence of middle stage reduction, combined with the continuity of non-metric attributes between early and middle stage flakes, makes differentiating middle stage from early stage flakes problematic. Correspondence analysis of the experimental dataset indicates that the greatest distinctions in terms of stage reduction can be seen between the early/middle category and the late category. The single strongest predictive attribute is size grade. However, the production of 3.2 mm sized flakes is so continuous across each stage that platform facet count and dorsal scar count must be used to distinguish late stage flakes from non-classifiable debris.

To test these results, the debitage from three archaeological sites was reanalyzed to examine any changes in the reported stage assignment profiles. At 22FO1515 and 22FO1546, the reanalysis supports the previous assessment that core reduction and bifacial preform shaping were the predominant trajectories pursued, and it pushes the overall profiles of these assemblages towards the early/middle stage, with comparatively small portions of late stage reduction represented. At 22FO1545, the reanalysis indicates that almost all knapping activities were during the early/middle stage reduction, which contradicts the previous findings. However, the absence of 3.2 mm size grade material means that definite conclusions surrounding site function are not practical. Finally, a correspondence analysis was performed incorporating the archaeological and experimental data. The results demonstrated that the methodology derived from the experimental dataset was consistent with a statistical analysis of the original archaeological data. The implications for these results are discussed in the following chapter.

CHAPTER VI – INTERPRETATIONS AND CONCLUSIONS

Experimental Knapping and the Pine Hills of Mississippi

This research is one example of the utility of experimental knapping in shaping the way debitage analysis is performed. Multiple researchers have demonstrated this point (Bradbury and Carr 1995, 2004, 2014; Magne 1985; Prasciunas 2007; Shott 1996) but the applicability of findings to various environments and the role that raw material plays in the interpretation of lithic remains have yet to be fully defined. The Pine Hills of Mississippi has enjoyed a marked increase in the amount of fieldwork and research attention given it, and therefore deserves increased theoretical consideration. The acidic nature of local soils often leaves few cultural materials to recover, but lithic remains appear to be a lone constant in the face of an otherwise pronounced absence. As such, it serves as a still untapped resource for lithic analysts and lithic analysis theory.

Based on the differences between the prior stage based experiments and those presented here, the necessity of continued experimentation is well demonstrated. In contrast to conclusions reported by others, correspondence analysis of the present experiments indicates that size grade is the strongest predictor of early and middle stage flakes. Flakes retained in the 25.4 mm, 12.7 mm, and 6.4 mm screens could reliably and accurately be classified as belonging to the early and middle stages. The continuity of attributes that occur across these two stages, however, obscures their separation in the laboratory setting. This was compounded by the relatively low occurrence of middle stage flakes in the experimental assemblage.

Flakes that fall into the 3.2 mm screen cannot be categorized as easily. Rather, the experimental data shows that flakes of this size are produced throughout the knapping continuum, though they are most indicative of the late stage of formalized bifacial tool manufacture. To properly sort this material, flakes had to be examined for their platform facets and dorsal scars; two or three facets, and the presence of two or more dorsal scars warranted inclusion in the final reduction stage. All other material in this size grade is undiagnostic but represents a more complete picture of knapping activities.

The inability to properly sort middle stage flakes from early stage flakes appears to be due to the size and shape of Citronelle gravel material. As discussed earlier in Chapter II, Citronelle gravel, when properly heat treated, is a very high quality knapping material and is widely distributed across the landscape. However, it only occurs in cobble form, usually in pieces smaller than the average fist. Because it is so restricted in size and shape, restrictions on the final tool form naturally follow. In order to produce a bifacial tool, a knapper must account for this and plan accordingly. Significant thinning and shaping must be performed together during the initial stages of manufacture, while any subsequent bifacial thinning is performed situationally. If not done correctly, the cobble is abandoned, and the process must be restarted. This dimension of Citronelle gravels is distinct from other raw materials. While other replication experiments utilize quarried nodules or larger, tabular varieties of tool stone, Citronelle gravel requires a unique method of attack in order to successfully produce a bifacial tool. It is in this way that raw material can affect the outcome of knapping activities, and therefore, the means by which we understand them.

The high occurrence of 3.2 mm sized flakes across all stages is informative on multiple levels. First, as has been discussed elsewhere, standardized archaeological recovery procedure for the Pine Hills of Mississippi is not likely to capture evidence of this material in the course of initial testing. As a result, sites potentially go undocumented or destroyed. Much attention has been called to this effect, and a movement to update this procedure is growing in size. And, if this material is to be collected, it must also be properly understood. Second, the production of 3.2 mm material in the early and middle stages is a byproduct of both the fine knapping quality of Citronelle gravel and the natural size of the material. The high quality produces a more brittle striking edge that is prone to breaking or crushing without releasing the desired flake. To effectively remove the necessary piece (such as early or middle stage thinning), platforms must be stiffened by grinding or altering the striking angle. When this occurs, small flakes and shatter are produced, which can mimic the appearance of late stage flakes. The analytical methods presented in this research allow for the accurate and reliable segregation of this non-diagnostic material.

Applicability and Implications for Archaeological Analysis

In applying the experimental results to three local archaeological sites, a more precise image of past lithic reduction activities, and therefore site functions, was produced. The Citronelle gravel debitage recovered from 22FO1515 and 22FO1546 were shown to be much more a result of the early and middle stages of bifacial reduction, while late stage reduction was minimally represented. This differed slightly from the original analyses, revealing a more precise image of reduction strategies. The reexamination of 22FO1545 produced a much different picture of past knapping activities. Rather than mostly early stage, along with some representation of middle and late stage flakes, only early and middle stages were well represented. Almost no evidence of late stage tool formalization or maintenance was found. These results were corroborated by subjecting the archaeological data to correspondence analysis in conjunction with the controlled experiment data. The statistical output for all three sites mirrored the results of the stage assignment reanalysis, giving strong support that the method presented in this study is both accurate and reliable.

Settlement and Technological Organization at 22FO1515

The results of the debitage reanalysis for 22FO1515 give way to meaningful interpretations of prehistoric settlement and technological organization. The high amounts of core reduction and bifacial tool shaping, with low amounts of tool formalization and maintenance, are indicative of reduction trajectories that were focused on the production of bifacial preforms. This conclusion is bolstered by the recovery of notable quantities of tested cobbles, bifacial tools and biface production failures in association with Feature 2. The production of bifacial and expedient tools led to the conclusion that 22FO1515 served as a residential base camp within a mobile forager adaptation system. The technological strategies reflected in the debitage are suggestive of Nelson's (1991) description of flexible tools. Because the Pine Hills environment was rich with exploitable, unpredictable resources, a flexible toolkit would be able to address whatever task was encountered in the course of foraging activities. The restrictions placed on final tool form by the raw nature of Citronelle gravels mean that a flexible bifacial preform would be even more maximizing for this reason, as any degree of versatility would be limited by their small size. Although bifacial tools require much more time and attention to manufacture, they represent a significant advantage to populations in environments well-endowed with exploitable tool resources. Cobbles could be retrieved from nearby Davis Creek and worked into bifacial preforms, while potentially useful flakes could be collected and reshaped as necessary for use while in camp. Bifaces could then be carried off-site to be shaped and hafted when needed. Standardized shapes allow other tool elements, such as arrow or dart shafts, to be recycled multiple times. The small size of these bifaces means several could be carried in a small pouch with relatively little burden placed on the end user.

Settlement and Technological Organization at 22FO1546

The reduction stage profile for the debitage recovered at 22FO1546 indicates it, like 22FO1515, served as a residential base camp within a mobile forager adaptation system. Core reduction and bifacial shaping constitute the bulk of the assemblage, while tool formalization and maintenance is ephemerally represented. Though smaller in number, the variety of tools in the assemblage suggests that it was occupied in a similar manner as 22FO1515. Phase II excavation produced multiple retouched or utilized flakes as well as several biface fragments. This, in addition to the presence of baked clay hearths, exhibits a pattern of residential activities. Foraging hunter-gatherers, moving across the landscape, likely found the ridgetop on which this site sits to be a productive location. Raw tool stone was readily available in Davis Creek and could have been shaped into bifacial preforms and expedient tools in preparation for the next relocation event.

The Problem of Standardized Recovery Methods

Analysis of the debitage from 22FO1545 was unable to determine with sufficient certainty the nature of reduction trajectories employed by its prehistoric inhabitants. Core reduction produced almost all of the debitage recovered during testing, while virtually no evidence of tool formalization was recovered. Because the site had been significantly damaged, no site functions can be determined.

The inability to come to a firmer conclusion regarding the settlement organization of 22FO1545 is primarily a product of the recovery methods used to collect cultural remains. The use of surface collection limits what data can be collected from Pine Hills sites, in that late stage flakes go unidentified. This type of stage assignment profile is likely similar to situations where 6.4 mm screens are used, such as standardized investigations of unexamined land. The inability to capture small, late stage flakes will leave noticeable gaps in the data, as 22FO1545 demonstrates.

The strong evidence for residential base camps, such as at 22FO1515 and 22FO1546, implies the existence of numerous special purpose foraging sites where late stage and retouch flakes may be located. While several of these sites have been reported, many more likely go unnoticed, and the use of 3.2 mm screens is paramount to their recognition in the archaeological record. In the best of all worlds, the use of 3.2 mm screens would be standard procedure in the Pine Hills and other regions where prehistoric signatures rest in the form of small retouch flakes. However, like most things, archaeology is bound by concerns of time and budget. Therefore, it is recommended that 3.2 mm screens be used in the delineation of positive test locations during Phase I investigation and any Phase II or Phase III testing that may result. This compromise would prevent the unnecessary wasting of resources in unfavorable soil conditions, while insuring that identified cultural materials are recovered to the fullest extent possible.

Cautious Admonitions

This study is not without limitations. First, because the replication experiments were conducted with Citronelle gravel cherts, the application of these results to other locations or other materials is advised with caution. However, these results may prove useful in situations which mirror those presented here. Second, because the experimental replication trajectories presented here focused on bifacial tools, the relationship between Citronelle gravel flake attributes and core reduction is not well understood. Other researchers have noted similarities in the earliest stages of biface manufacture and core reduction, and it is with this assumption in mind that the present conclusions are rendered. Further experimentation can more fully explore the relationship between core reduction and biface production with respect to Citronelle gravel chert.

Conclusions

The primary goal of this study was to better understand lithic remains in the Pine Hills region of Mississippi through the use of experimental replication. The study drew on the theoretical foundations of hunter-gatherer settlement organization, lithic technological organization, and the replication of stone tools. The results of the knapping experiments demonstrate the power that replication experimentation has in facilitating more robust analysis of local archaeological sites. Further experimentation can only refine these results.

For local Citronelle gravel material, only two stages can be accurately identified. These correspond with what other researchers define as early/middle stage and late stage. The shape and size of this material plays a significant role in this outcome, and as such, Citronelle gravels should be analyzed accordingly. Similarly, the use of 3.2 mm screen is necessary for identifying the full range of the knapping continuum. Its use in site delineation and Phase II and Phase III recovery can accomplish this feat without undue burden on investigators.

The results generated here were successfully used to more accurately identify the range of stage reduction at three local archaeological sites. Two of these are highly suggestive of a well-adapted, foraging oriented group that inhabited the Pine Hills for large periods of time. These findings add to the growing body of research that shows that the Pine Hills region of Mississippi was home to well-adapted, prehistoric hunter-gatherers.

APPENDIX A – Flake Attribute Coding Sheet

SG = Size Grade
- 1 = 1 inch (2.54cm)
- 2 = ½ inch (1.27cm)
- 3 = ¼ inch (0.64 cm)
- 4 = 1/8 inch (0.32 cm)

WT = Weight in grams

RM = Raw Material
- 1 = Local Chert Gravel – Heat Treated
- 2 = Local Chert Gravel

PO = Portion
- 1 = Complete
- 2 = Proximal (platform bearing)
- 3 = Medial
- 4 = Distal
- 5 = Blocky Fragment / Shatter
- 6 = Split Longitudinally
- 7 = Potlid / Fire Shatter
- 9 = Other: Go To Lithic category

PL = Platform
- 1 = No Cortex; Non-Lipped
- 2 = Cortex; Non-Lipped
- 3 = No Cortex; Lipped
- 4 = Cortex; Lipped
- 5 = Indiscernible Cortex; Lipped
- 6 = Indiscernible Cortex; Non-Lipped
- 7 = Incomplete / Not Present

F = Facet Count
- 0 = Not present
- 1 = 1 Facet
- 2 = 2 Facets
- 3 = 3 Facets
- 4 = 4 Facets
- 5 = 5 Facets
- 6 = More than 5 Facets
- 7 = Incomplete

CO = Cortex
- 0 = 0%
- 1 = 1-25%
- 2 = 26-50%
- 3 = 51-75%
- 4 = 75-99%
- 5 = 100%

DS = Dorsal Scars
- 0 = Cortex
- 1 = 1 Scar
- 2 = 2 Scars
- 3 = 3 Scars
- 4 = 4 Scars
- 5 = 5 Scars
- 6 = More than 5 Scars
- 9 = Indiscernible

MO = Modification
- 0 = None obvious
- 1 = Retouched – one edge
- 2 = Retouched – two plus edges
- 3 = Utilization – possible
- 4 = Utilization damage – obvious

RD = Reduction
- 1 = Bipolar
- 2 = Bifacial Thinning
- 3 = Notching
- 4 = Other / Standard
- 5 = Edge Grinding
- 6 = Edge Retouch / Straightening

PT = Percussor Type
- 1 = Hard Hammer (HH)
- 2 = Soft Hammer (SH)
- 3 = Pressure Flaker (PF)

APPENDIX B – Experimental Coding Data

Table A1.

Experiment 4 Flake Attributes

Flake #	SG	WT	RM	PO	PL	F	CO	DS	MO	RD	PT
1	2	12.11	1	6	4	0	5	0	0	4	1
1	2	0.38	1	6	4	0	5	0	0	4	1
2	4	0.02	1	1	4	0	0	1	0	5	1
2	4	0.01	1	4	7	7	0	1	0	5	1
3	3	0.16	1	2	2	0	5	0	0	4	1
4	3	0.20	1	2	1	1	1	2	0	4	1
4	3	0.23	1	4	7	7	2	1	0	4	1
4	4	0.11	1	1	1	1	3	1	0	4	1
5	3	0.23	1	2	3	1	2	1	0	4	2
6	4	0.05	1	1	4	0	0	2	0	5	1
6	4	0.01	1	1	4	0	0	1	0	5	1
6	4	0.01	1	6	7	7	0	1	0	5	1
7	2	10.08	1	2	4	0	5	0	0	4	1
7	4	0.11	1	4	7	7	5	0	0	4	1
7	4	0.22	1	1	4	0	0	2	0	4	1
8	2	2.56	1	2	3	1	4	1	0	4	2
8	4	0.16	1	4	7	7	3	1	0	4	2
9	2	0.79	1	4	7	7	1	1	0	4	2
9	3	0.79	1	2	3	2	3	2	0	4	2
10	4	0.08	1	1	3	3	1	2	0	4	2
10	4	0.01	1	1	4	0	0	1	0	4	1
10	4	0.02	1	4	7	7	0	2	0	4	2
10	4	0.01	1	5	7	7	0	9	0	4	2
11	2	2.07	1	1	4	0	1	4	0	4	1
11	4	0.04	1	5	7	7	2	9	0	4	1
12	3	0.60	1	6	7	7	1	2	0	4	1
12	4	0.06	1	6	7	7	0	1	0	4	1
13	4	0.03	1	5	7	7	0	9	0	4	1
13	4	0.01	1	1	4	0	0	1	0	4	1
13	4	0.05	1	5	7	7	1	9	0	4	1
14	4	0.26	1	6	7	7	1	3	0	4	1
14	4	0.08	1	5	7	7	1	9	0	4	1
14	4	0.06	1	5	7	7	1	9	0	4	1
14	4	0.03	1	1	3	1	0	2	0	4	1
15	1	10.25	1	1	4	0	1	6	0	4	1
16	3	0.61	1	3	7	7	2	1	0	4	1

Table A1 (continued).

16	3	0.35	1	6	7	7	1	2	0	4	1
16	4	0.03	1	6	7	7	0	9	0	4	1
17	4	0.12	1	2	3	1	2	2	0	4	2
17	4	0.01	1	3	7	7	0	1	0	4	2
18	2	1.94	1	1	2	0	1	1	0	4	1
19	4	0.04	1	5	7	7	0	9	0	5	1
20	4	0.13	1	4	7	7	1	2	0	5	1
20	4	0.09	1	3	7	7	2	2	0	5	1
21	3	0.29	1	1	4	0	0	1	0	4	1
22	4	0.23	1	5	7	7	2	9	0	4	1
23	4	0.14	1	3	7	7	1	2	0	4	1
23	4	0.05	1	4	7	7	1	1	0	4	1
24	3	1.94	1	1	2	0	1	4	0	4	1
24	3	0.74	1	6	7	7	1	3	0	4	1
24	3	0.67	1	4	7	7	4	4	0	4	1
24	4	0.05	1	2	1	1	4	1	0	4	1
25	4	0.02	1	5	7	7	0	9	0	5	1
26	2	0.75	1	1	3	1	4	2	0	4	2
27	3	0.09	1	4	7	7	1	3	0	4	2
27	3	0.15	1	2	3	2	1	2	0	4	2
27	4	0.07	1	3	7	7	1	1	0	4	2
27	4	0.13	1	4	7	7	3	1	0	4	2
28	3	0.50	1	1	3	2	1	2	0	4	2
29	3	0.55	1	2	4	0	1	2	0	4	2
29	3	0.57	1	4	7	7	1	4	0	4	2
30	2	0.44	1	1	3	4	1	4	0	4	2
31	3	0.06	1	4	7	7	0	1	0	4	2
32	3	0.63	1	1	3	1	0	5	0	4	2
33	4	0.03	1	3	7	7	1	4	0	4	1
34	4	0.08	1	6	7	7	0	3	0	4	1
34	4	0.01	1	6	7	7	0	2	0	4	1
35	4	0.08	1	4	7	7	2	2	0	4	1
36	2	1.32	1	1	2	0	1	6	0	4	1
37	2	1.15	1	4	7	7	3	3	0	2	2
38	3	0.47	1	2	4	0	1	2	0	4	2
39	3	0.22	1	1	4	0	1	3	0	4	2
40	4	0.25	1	6	7	7	3	2	0	4	2
40	4	0.12	1	6	7	7	1	9	0	4	2
40	4	0.02	1	3	7	7	1	1	0	4	2
40	4	0.05	1	5	7	7	0	9	0	4	2
40	4	0.03	1	4	7	7	1	1	0	4	2
41	3	0.64	1	2	3	2	3	1	0	2	2

Table A1 (continued).

41	4	0.03	1	4	7	7	1	3	0	2	2
42	4	0.09	1	1	4	0	1	2	0	4	2
43	4	0.12	1	3	7	7	0	4	0	2	2
43	3	0.31	1	4	7	7	0	6	0	2	2
44	4	0.05	1	4	7	7	0	2	0	5	1
45	4	0.05	1	3	7	7	0	4	0	2	1
45	4	0.12	1	4	7	7	0	4	0	2	1
46	4	0.04	1	1	3	2	0	3	0	6	3
46	4	0.11	1	4	7	7	0	2	0	6	3
47	4	0.03	1	2	3	1	0	2	0	6	3
47	4	0.16	1	4	7	7	0	3	0	6	3
48	4	0.08	1	2	3	2	0	3	0	6	3
48	4	0.08	1	4	7	7	0	3	0	6	3
49	3	0.26	1	3	7	7	0	2	0	6	3
50	4	0.01	1	6	7	7	5	0	0	6	3
50	4	0.03	1	6	7	7	5	0	0	6	3
51	4	0.04	1	2	3	1	0	2	0	6	3
52	4	0.06	1	2	3	2	2	1	0	6	3
53	4	0.03	1	1	3	2	5	0	0	6	3
54	4	0.01	1	1	4	0	0	2	0	6	3
54	4	0.04	1	1	4	0	0	2	0	6	3
55	4	0.06	1	2	4	0	0	2	0	6	3
56	4	0.02	1	1	4	0	0	2	0	6	3
57	4	0.07	1	1	4	0	0	2	0	6	3
58	4	0.08	1	1	3	2	0	3	0	6	3
59	4	0.03	1	1	1	2	0	2	0	6	3
60	4	0.04	1	1	3	2	2	1	0	6	3
61	4	0.05	1	2	3	1	0	3	0	6	3
62	4	0.05	1	2	3	2	3	1	0	6	3
63	4	0.03	1	2	1	1	0	2	0	6	3
64	4	0.10	1	1	3	2	0	6	0	6	3
65	4	0.04	1	1	3	1	0	3	0	6	3
66	4	0.12	1	2	3	1	0	4	0	6	3
67	4	0.04	1	2	3	1	0	2	0	6	3
68	4	0.04	1	2	3	2	0	2	0	6	3
69	4	0.03	1	2	3	1	0	2	0	6	3
69	4	0.01	1	4	7	7	0	2	0	6	3
70	4	0.03	1	1	3	1	0	3	0	6	3
71	4	0.08	1	2	3	1	0	3	0	6	3
72	4	0.05	1	2	3	2	0	3	0	6	3
72	4	0.02	1	4	7	7	0	2	0	6	3
73	4	0.05	1	1	3	3	0	3	0	6	3

Table A1 (continued).

74	4	0.05	1	2	3	2	0	3	0	6	3
75	4	0.08	1	2	1	1	0	6	0	6	3
75	4	0.04	1	4	7	7	0	2	0	6	3
76	4	0.08	1	1	3	1	0	3	0	6	3
77	4	0.04	1	1	3	1	0	3	0	6	3
78	4	0.03	1	1	1	2	0	3	0	6	3
79	4	0.02	1	1	1	1	0	2	0	6	3
80	4	0.05	1	1	3	3	0	3	0	6	3
81	4	0.01	1	4	7	7	0	2	0	6	3
81	4	0.02	1	2	3	2	0	2	0	6	3
82	3	0.17	1	1	3	1	1	3	0	6	3
83	4	0.06	1	1	4	0	0	2	0	6	3
84	4	0.03	1	2	3	2	0	2	0	6	3
85	4	0.01	1	2	3	1	0	2	0	6	3
86	4	0.02	1	2	3	2	0	2	0	6	3
86	4	0.05	1	4	7	7	0	3	0	6	3
87	4	0.01	1	2	3	1	1	3	0	6	3
88	4	0.01	1	4	7	7	0	2	0	6	3
89	4	0.04	1	1	3	3	0	2	0	6	3
90	4	0.03	1	3	7	7	0	2	0	6	3
90	3	0.02	1	2	3	1	0	2	0	6	3
90	4	0.02	1	4	7	7	0	3	0	6	3
91	4	0.01	1	4	7	7	0	2	0	6	3
91	4	0.05	1	2	3	2	0	2	0	6	3
92	4	0.03	1	2	3	1	0	2	0	6	3
93	4	0.08	1	2	3	2	0	3	0	6	3
93	4	0.06	1	4	7	7	0	3	0	6	3
94	4	0.02	1	1	3	1	0	2	0	6	3
95	4	0.10	1	1	3	3	0	4	0	3	3
96	4	0.09	1	1	3	2	0	4	0	3	3
97	4	0.01	1	1	3	1	0	2	0	3	3
98	4	0.03	1	2	3	1	0	2	0	3	3
99	4	0.01	1	1	3	1	0	3	0	3	3
100	4	0.03	1	1	3	2	1	3	0	3	3
101	4	0.06	1	1	3	3	0	4	0	3	3
102	4	0.07	1	2	3	2	0	3	0	3	3
102	4	0.01	1	3	7	7	0	2	0	3	3
102	4	0.02	1	4	7	7	0	3	0	3	3
103	4	0.08	1	2	3	2	0	2	0	3	3
103	4	0.01	1	4	7	7	0	3	0	3	3
104	4	0.05	1	1	3	2	1	4	0	3	3
105	4	0.02	1	1	3	2	0	2	0	3	3

Table A1 (continued).

105	4	0.07	1	1	3	1	0	4	0	3	3
106	4	0.08	1	1	3	2	0	2	0	3	3

Table A2.

Experiment 13 Flake Attributes

Flake #	SG	WT	RM	PO	PL	F	CO	DS	MO	RD	PT
1	2	1.23	1	1	2	0	5	0	0	4	1
2	3	0.33	1	4	7	7	4	1	0	4	1
3	3	0.46	1	1	4	0	0	2	0	4	1
3	4	0.02	1	2	1	1	1	2	0	4	1
3	4	0.02	1	4	7	7	0	1	0	4	1
4	4	0.08	1	1	2	0	0	2	0	5	1
5	2	3.58	1	4	7	7	3	3	0	4	1
5	3	0.33	1	2	4	0	1	2	0	4	1
6	3	0.20	1	4	7	7	5	0	0	4	1
6	3	0.33	1	1	3	2	0	0	0	4	1
7	1	21.40	1	1	2	0	4	2	0	4	1
7	3	0.03	1	1	4	0	0	1	0	4	1
7	3	0.13	1	4	7	7	5	0	0	4	1
7	4	0.01	1	4	7	7	1	1	0	4	1
7	4	0.02	1	5	7	7	2	9	0	4	1
7	4	0.01	1	4	7	7	0	1	0	4	1
8	1	28.64	1	4	7	7	0	2	0	4	1
8	2	1.50	1	3	7	7	1	1	0	4	1
8	2	2.59	1	2	4	0	0	2	0	4	1
8	2	3.49	1	4	7	7	2	1	0	4	1
8	3	1.28	1	3	7	7	0	2	0	4	1
8	4	0.21	1	5	7	7	0	9	0	4	1
8	4	0.05	1	3	7	7	0	1	0	4	1
8	4	0.03	1	4	7	7	1	1	0	4	1
8	4	0.16	1	6	2	0	0	2	0	4	1
8	4	0.04	1	3	7	7	0	1	0	4	1
8	4	0.06	1	3	7	7	0	2	0	4	1
9	2	1.71	1	3	7	7	1	1	0	4	2
9	2	5.61	1	4	7	7	4	2	0	4	2
9	3	0.25	1	6	7	7	0	1	0	4	2
9	3	0.22	1	6	7	7	0	1	0	4	2
9	4	0.10	1	5	7	7	5	9	0	4	2

Table A2 (continued).

9	4	0.06	1	5	7	7	2	9	0	4	2
9	4	0.01	1	3	7	7	0	2	0	4	2
9	4	0.01	1	3	7	7	0	1	0	4	2
10	3	1.73	1	2	4	0	0	1	0	4	2
10	3	0.18	1	2	4	0	0	1	0	4	2
11	3	0.52	1	5	7	7	1	9	0	4	2
11	3	0.05	1	4	7	7	0	1	0	4	2
11	3	0.83	1	2	1	1	2	1	0	4	2
11	3	0.28	1	5	7	7	3	9	0	4	2
11	3	0.11	1	4	7	7	0	3	0	4	2
11	3	0.17	1	3	7	7	2	1	0	4	2
11	4	0.08	1	4	7	7	0	3	0	4	2
11	4	0.02	1	3	7	7	0	1	0	4	2
11	4	0.03	1	4	7	7	1	1	0	4	2
11	4	0.04	1	3	7	7	0	1	0	4	2
11	4	0.02	1	5	7	7	2	9	0	4	2
12	2	7.95	1	5	7	7	3	9	0	4	2
12	4	0.13	1	1	3	1	0	3	0	4	2
14	4	0.22	1	2	2	0	0	2	0	4	2
14	4	0.08	1	4	7	7	0	2	0	4	2
15	2	5.34	1	1	4	0	0	5	0	4	2
16	2	8.54	1	1	3	1	1	2	0	4	2
17	2	3.80	1	1	3	1	2	2	0	4	2
18	2	4.97	1	1	4	0	1	5	0	4	1
19	3	0.81	1	1	2	0	0	3	0	4	1
20	3	0.93	1	4	7	7	0	3	0	4	1
21	2	6.40	1	2	1	1	1	3	0	4	1
21	2	1.53	1	4	7	7	1	1	0	4	1
21	3	0.15	1	5	7	7	0	9	0	4	1
22	2	3.98	1	4	7	7	0	5	0	4	2
23	2	2.31	1	4	7	7	0	5	0	4	2
23	2	2.73	1	2	4	0	0	4	0	4	2
23	3	0.32	1	1	4	0	0	2	0	4	2
23	3	0.38	1	1	4	0	0	4	0	4	2
23	3	0.27	1	4	7	7	0	2	0	4	2
23	3	0.09	1	4	7	7	0	2	0	4	2
23	4	0.04	1	4	7	7	0	2	0	4	2
23	4	0.07	1	4	7	7	0	2	0	4	2
23	4	0.05	1	3	7	7	0	2	0	4	2
23	4	0.01	1	4	7	7	0	1	0	4	2
24	3	0.08	1	4	7	7	0	1	0	4	2
24	3	0.11	1	3	7	7	0	2	0	4	2

Table A2 (continued).

24	4	0.09	1	4	7	7	0	3	0	4	2
25	2	0.93	1	4	7	7	5	0	0	4	2
25	2	0.74	1	2	3	2	5	0	0	4	2
25	4	0.01	1	4	7	0	5	0	0	4	2
26	2	1.07	1	5	7	7	1	9	0	4	2
27	3	0.27	1	4	7	7	0	2	0	4	2
27	2	3.86	1	1	1	2	3	1	0	4	2
28	3	0.30	1	2	4	0	0	6	0	4	2
28	3	0.41	1	3	7	7	0	3	0	4	2
28	4	0.01	1	4	7	7	0	2	0	4	2
29	3	0.16	1	1	4	0	0	2	0	4	2
29	4	0.08	1	2	4	0	0	2	0	4	2
30	3	0.11	1	4	7	7	0	2	0	4	2
30	3	0.04	1	3	7	7	0	2	0	4	2
30	4	0.04	1	5	7	7	0	9	0	4	2
31	3	0.27	1	3	7	7	0	1	0	4	2
31	3	0.33	1	4	7	7	0	2	0	4	2
31	3	0.20	1	2	4	0	0	3	0	4	2
31	4	0.05	1	5	7	7	0	9	0	4	2
31	4	0.03	1	3	7	7	0	3	0	4	2
31	4	0.02	1	4	7	7	0	3	0	4	2
32	2	1.53	1	1	1	2	1	2	0	4	2
32	3	0.83	1	5	7	7	2	9	0	4	2
33	3	0.13	1	1	3	2	0	3	0	4	2
33	4	0.01	1	5	7	7	0	9	0	4	2
34	3	0.23	1	4	7	7	0	9	0	4	1
35	3	0.33	1	2	3	2	5	0	0	4	2
35	3	0.71	1	4	7	7	3	1	0	4	2
35	4	0.05	1	4	7	7	0	1	0	4	2
36	3	0.10	1	2	1	2	0	3	0	4	1
37	4	0.03	1	1	3	2	0	2	0	5	1
37	4	0.03	1	1	3	2	0	2	0	5	1
37	3	0.01	1	1	3	1	0	2	0	5	1
38	2	10.17	1	2	4	0	0	6	0	4	1
38	4	0.08	1	4	7	7	0	3	0	4	1
39	4	0.04	1	1	6	1	0	9	0	4	1
40	2	0.96	1	2	3	3	0	6	0	4	2
40	4	0.03	1	4	7	7	0	1	0	4	2
40	4	0.03	1	4	7	7	0	2	0	4	2
41	2	0.84	1	4	7	7	3	2	0	4	1
42	3	0.69	1	1	1	3	0	2	0	4	1
42	4	0.02	1	5	7	7	0	2	0	4	1

Table A2 (continued).

42	4	0.02	1	5	7	7	0	9	0	4	1
43	3	0.50	1	1	4	0	0	6	0	4	1
43	3	0.10	1	4	7	7	0	4	0	4	1
43	4	0.03	1	1	3	1	0	2	0	4	1
44	2	2.43	1	1	2	0	0	5	0	4	1
45	3	0.35	1	1	4	2	0	4	0	4	1
45	4	0.02	1	5	7	7	0	9	0	4	1
46	3	0.05	1	5	7	7	0	9	0	5	1
46	4	0.03	1	1	3	1	0	9	0	5	1
47	3	0.63	1	1	4	0	0	4	0	4	1
47	4	0.01	1	5	7	7	0	9	0	4	1
48	4	0.05	1	2	3	1	0	4	0	4	1
49	3	0.60	1	2	1	1	0	3	0	4	1
49	3	0.21	1	3	7	7	0	1	0	4	1
50	4	0.05	1	1	1	1	0	2	0	4	1
51	3	0.24	1	1	4	1	0	2	0	4	1
51	3	0.11	1	5	7	7	0	9	0	4	1
52	3	0.09	1	1	1	1	0	4	0	4	1
53	4	0.04	1	3	7	7	0	3	0	4	1
54	3	0.40	1	4	7	7	0	4	0	4	1
55	3	0.59	1	1	4	1	0	4	0	4	1
55	4	0.04	1	1	3	1	0	2	0	4	1
56	4	0.01	1	5	7	7	0	9	0	5	1
56	4	0.04	1	4	7	7	0	9	0	5	1
57	3	0.26	1	2	1	2	5	0	0	4	1
57	4	0.03	1	2	4	0	0	2	0	4	1
57	4	0.05	1	1	4	0	0	3	0	4	1
58	4	0.06	1	4	7	7	0	3	0	4	1
58	4	0.04	1	5	7	7	0	9	0	4	1
58	4	0.04	1	2	4	0	0	1	0	4	1
59	3	0.19	1	2	3	1	0	3	0	4	1
59	3	0.12	1	4	7	7	0	2	0	4	1
59	4	0.06	1	2	1	1	0	3	0	4	1
59	4	0.07	1	5	7	7	0	9	0	4	1
59	4	0.04	1	1	5	1	0	3	0	4	1
60	3	0.68	1	1	3	2	3	1	0	4	1
60	3	0.79	1	4	7	7	4	1	0	4	1
60	4	0.04	1	4	7	7	0	3	0	4	1
61	4	0.03	1	4	7	7	0	1	0	4	1
61	4	0.06	1	2	3	1	0	2	0	4	1
62	4	0.03	1	2	4	0	0	2	0	4	1
63	3	0.06	1	1	1	1	5	0	0	4	1

Table A2 (continued).

64	2	2.35	1	1	3	2	2	2	0	4	1
64	4	0.05	1	5	7	7	3	9	0	4	1
65	3	0.21	1	2	1	2	0	3	0	4	1
65	3	0.17	1	1	4	1	0	1	0	4	1
66	3	0.03	1	2	3	1	0	3	0	4	1
67	3	0.58	1	1	4	1	0	2	0	4	1
67	4	0.01	1	5	7	7	0	9	0	4	1
67	4	0.04	1	5	7	7	0	9	0	4	1
67	4	0.05	1	3	7	7	0	1	0	4	1
68	2	1.16	1	6	7	7	0	5	0	4	1
68	2	1.13	1	4	7	7	0	6	0	4	1
68	3	0.59	1	5	7	7	0	9	0	4	1
68	4	0.05	1	4	7	7	0	3	0	4	1
68	4	0.02	1	4	7	7	0	3	0	4	1
69	3	0.13	1	1	4	0	0	2	0	4	1
70	3	0.37	1	2	4	0	0	1	0	4	1
71	3	0.70	1	1	4	0	0	4	0	4	1
71	4	0.07	1	5	7	7	0	9	0	4	1
71	4	0.01	1	6	7	7	0	1	0	4	1
72	3	0.25	1	4	7	7	4	1	0	4	1
73	2	1.91	1	1	1	3	4	1	0	4	1
73	4	0.16	1	1	3	1	0	3	0	4	1
73	4	0.04	1	4	7	7	0	2	0	4	1
74	3	0.71	1	1	3	2	1	5	0	2	1
75	4	0.04	1	1	1	1	0	9	0	3	3
75	4	0.01	1	2	3	2	0	2	0	3	3
76	4	0.04	1	1	1	1	0	1	0	3	3
77	4	0.01	1	4	7	7	0	1	0	3	3
78	4	0.01	1	1	4	0	0	1	0	3	3
79	4	0.01	1	4	7	7	0	1	0	3	3
80	3	0.07	1	1	1	2	0	2	0	3	3
81	4	0.08	1	2	3	2	0	2	0	3	3
81	4	0.01	1	4	7	7	0	2	0	3	3
81	4	0.05	1	6	3	1	0	1	0	3	3
82	3	0.16	1	1	1	2	0	4	0	3	3
83	4	0.06	1	6	7	7	0	2	0	3	3
83	4	0.03	1	6	7	7	0	1	0	3	3
83	4	0.01	1	4	7	7	0	2	0	3	3
84	4	0.03	1	2	1	2	0	4	0	3	3
84	4	0.07	1	4	7	7	0	4	0	3	3
85	4	0.03	1	5	7	7	0	9	0	3	3
85	4	0.06	1	4	7	7	2	2	0	3	3

Table A2 (continued).

86	4	0.01	1	4	7	7	0	2	0	3	3
86	4	0.03	1	6	7	7	0	9	0	3	3
87	4	0.08	1	2	4	0	0	3	0	3	3
87	4	0.01	1	4	7	7	0	1	0	3	3
87	4	0.01	1	4	7	7	0	4	0	3	3
87	4	0.03	1	4	7	7	0	3	0	3	3
88	3	0.18	1	1	1	2	0	3	0	6	3
89	3	0.12	1	1	3	1	0	3	0	6	3
91	4	0.02	1	4	7	7	1	3	0	6	3
91	4	0.01	1	2	3	3	2	1	0	6	3
92	4	0.03	1	2	3	3	0	2	0	6	3
92	4	0.02	1	4	7	7	0	3	0	6	3
93	3	0.10	1	2	3	2	0	3	0	6	3
93	4	0.03	1	4	7	7	0	5	0	6	3
93	4	0.06	1	3	7	7	0	3	0	6	3
94	4	0.07	1	1	3	1	0	6	0	6	3
94	4	0.05	1	4	7	7	0	4	0	6	3
94	4	0.05	1	4	7	7	0	3	0	6	3
95	4	0.03	1	2	4	1	0	3	0	6	3
95	4	0.01	1	4	7	7	0	1	0	6	3
95	4	0.03	1	4	7	7	0	3	0	6	3
96	3	0.10	1	3	7	7	0	3	0	6	3
96	4	0.03	1	4	7	7	1	3	0	6	3
96	4	0.02	1	3	7	7	0	3	0	6	3
96	4	0.01	1	3	7	7	0	3	0	6	3
96	4	0.01	1	3	7	7	0	1	0	6	3
96	4	0.03	1	3	7	7	0	2	0	6	3
96	4	0.04	1	3	7	7	0	2	0	6	3
97	3	0.17	1	1	3	3	0	4	0	6	3
98	4	0.12	1	1	3	2	1	1	0	6	3
98	4	0.05	1	4	7	7	1	3	0	6	3
99	3	0.10	1	1	3	2	2	2	0	6	3
100	4	0.05	1	4	7	7	1	3	0	6	3
100	4	0.03	1	2	3	1	2	1	0	6	3
101	4	0.01	1	1	3	1	0	5	0	6	3
102	4	0.04	1	1	1	1	0	5	0	6	3
103	4	0.03	1	1	4	1	0	3	0	6	3
104	4	0.08	1	5	7	7	1	9	0	6	3
105	4	0.04	1	2	3	2	0	3	0	6	3
105	4	0.04	1	4	7	7	0	2	0	6	3
106	4	0.02	1	1	4	0	0	4	0	6	3
107	4	0.01	1	1	3	2	0	3	0	6	3

Table A2 (continued).

108	4	0.01	1	3	7	7	0	3	0	6	3
109	4	0.10	1	1	3	2	0	4	0	6	3
110	4	0.04	1	2	3	2	0	3	0	6	3
111	4	0.04	1	2	3	3	0	5	0	6	3
111	4	0.05	1	4	7	7	0	3	0	6	3
112	4	0.03	1	5	7	7	0	9	0	6	3
113	3	0.11	1	4	7	7	0	2	0	6	3
114	3	0.48	1	4	7	7	0	6	0	6	3
114	4	0.05	1	2	1	2	0	3	0	6	3
115	4	0.02	1	3	7	7	0	3	0	4	1
115	4	0.03	1	2	1	2	0	2	0	4	1
116	4	0.03	1	5	7	7	0	9	0	6	3
117	4	0.01	1	2	1	2	0	2	0	6	3

Table A3.

Experiment 18 Flake Attributes

Flake #	SG	WT	RM	PO	PL	F	CO	DS	MO	RD	PT
1	2	7.21	1	1	4	0	5	0	0	4	1
2	4	0.01	1	1	3	1	1	1	0	5	1
2	4	0.03	1	1	2	0	0	1	0	5	1
3	4	0.03	1	5	7	7	2	9	0	4	1
3	4	0.12	1	5	7	7	2	9	0	4	1
4	2	10.54	1	2	3	1	4	1	0	4	1
4	3	0.28	1	4	7	7	5	0	0	4	1
4	4	0.28	1	4	7	7	5	0	0	4	1
4	4	0.10	1	5	7	7	2	9	0	4	1
5	3	0.97	1	1	3	1	2	2	0	4	1
5	3	0.18	1	4	7	7	0	2	0	4	1
5	3	0.31	1	4	7	7	1	2	0	4	1
5	4	0.10	1	5	7	7	0	9	0	4	1
5	4	0.01	1	1	3	1	0	3	0	4	1
5	4	0.05	1	3	7	7	0	1	0	4	1
5	4	0.03	1	5	7	7	1	9	0	4	1
5	4	0.02	1	3	7	7	0	1	0	4	1
6	3	0.58	1	1	4	0	2	1	0	4	1
7	4	0.20	1	3	7	7	5	0	0	4	1
7	4	0.06	1	4	7	7	5	0	0	4	1
8	2	12.49	1	2	4	0	5	0	0	4	1

Table A3 (continued).

8	3	0.35	1	5	7	7	2	9	0	4	1
8	3	0.11	1	4	7	7	0	2	0	4	1
8	4	0.15	1	4	7	7	3	1	0	4	1
8	4	0.05	1	5	7	7	0	1	0	4	1
9	4	0.25	1	4	7	7	3	1	0	4	1
9	4	0.06	1	4	7	7	1	2	0	4	1
9	4	0.03	1	5	7	7	0	9	0	4	1
9	4	0.02	1	1	4	0	0	1	0	4	1
9	4	0.06	1	5	7	7	1	9	0	4	1
9	4	0.04	1	1	2	0	0	2	0	4	1
10	4	0.08	1	2	3	2	5	0	0	4	1
10	4	0.01	1	4	7	7	0	1	0	4	1
10	4	0.06	1	4	7	7	5	1	0	4	1
11	4	0.12	1	1	4	0	0	2	0	5	1
11	4	0.03	1	2	3	2	0	1	0	5	1
12	2	10.58	1	1	4	0	4	2	0	4	1
13	4	0.21	1	4	7	7	3	1	0	4	1
14	3	0.31	1	4	7	7	1	3	0	4	1
14	4	0.01	1	4	7	7	1	2	0	4	1
15	3	1.69	1	1	1	2	4	1	0	4	1
15	4	0.07	1	5	7	7	2	9	0	4	1
16	4	0.08	1	5	7	7	0	9	0	4	1
17	3	0.34	1	2	2	0	0	2	0	4	1
17	3	0.48	1	4	7	7	4	1	0	4	1
17	3	0.26	1	3	7	7	0	2	0	4	1
17	4	0.01	1	4	7	7	0	2	0	4	1
17	4	0.03	1	6	7	7	0	2	0	4	1
17	4	0.03	1	4	7	7	1	1	0	4	1
18	4	0.08	1	1	1	2	3	1	0	4	1
18	4	0.04	1	4	7	7	2	1	0	4	1
18	4	0.05	1	1	1	2	1	1	0	4	1
18	4	0.06	1	4	7	7	3	1	0	4	1
19	4	0.03	1	3	7	7	0	1	0	5	1
19	4	0.08	1	1	1	1	0	2	0	5	1
19	4	0.04	1	5	7	7	0	9	0	5	1
20	3	0.56	1	6	7	7	5	0	0	4	1
20	3	0.84	1	6	7	7	4	2	0	4	1
20	4	0.01	1	4	7	7	4	1	0	4	1
20	4	0.03	1	4	7	7	5	0	0	4	1
20	4	0.03	1	3	7	7	0	1	0	4	1
21	2	1.74	1	4	7	7	3	2	0	4	2
21	2	2.10	1	2	4	0	1	2	0	4	2

Table A3 (continued).

21	4	0.12	1	5	7	7	1	9	0	4	2
21	4	0.01	1	4	7	7	0	1	0	4	2
21	4	0.13	1	4	7	7	2	1	0	4	2
22	4	0.01	1	3	7	7	0	2	0	5	2
22	4	0.01	1	1	1	2	0	1	0	5	2
22	4	0.05	2	5	7	7	1	9	0	5	2
23	3	1.31	1	2	3	1	4	3	0	4	2
23	3	0.52	1	4	7	7	2	1	0	4	2
23	4	0.04	1	1	3	1	0	1	0	4	2
24	2	0.87	1	2	3	1	1	3	0	4	2
24	3	0.46	1	4	7	7	0	4	0	4	2
24	3	0.48	1	4	7	7	2	1	0	4	2
24	4	0.08	1	2	3	1	0	2	0	4	2
24	4	0.23	1	3	7	7	0	2	0	4	2
25	2	2.81	1	1	3	2	2	3	0	4	2
26	2	0.49	1	1	3	1	0	4	0	4	2
27	3	0.45	1	1	4	0	0	2	0	4	2
27	4	0.01	1	4	7	7	0	2	0	4	2
28	4	0.06	1	1	3	1	0	3	0	4	2
28	4	0.13	1	4	7	7	0	4	0	4	1
29	3	0.61	1	1	1	1	4	1	0	4	1
29	4	0.03	1	4	7	7	5	0	0	4	1
31	3	0.40	1	4	7	7	1	5	0	4	1
31	4	0.02	1	4	7	7	0	3	0	4	1
32	4	0.03	1	1	1	1	0	3	0	4	1
33	2	0.78	1	6	7	7	1	4	0	4	1
33	3	0.42	1	6	7	7	0	3	0	4	1
33	3	0.21	1	4	7	7	1	2	0	4	1
33	4	0.01	1	2	1	1	0	1	0	4	1
33	4	0.05	1	5	7	7	0	9	0	4	1
33	4	0.04	1	5	7	7	0	9	0	4	1
33	4	0.03	1	4	7	7	1	1	0	4	1
33	4	0.01	1	4	7	7	1	1	0	4	1
33	4	0.01	1	4	7	7	1	1	0	4	1
33	4	0.04	1	1	2	0	0	2	0	4	1
33	4	0.04	1	4	7	7	0	3	0	4	1
33	4	0.01	1	4	7	7	1	1	0	4	1
33	4	0.01	1	3	7	7	0	2	0	4	1
34	1	16.45	1	4	7	7	2	5	0	4	1
34	3	0.39	1	2	1	2	0	1	0	4	1
34	4	0.11	1	5	7	7	2	9	0	4	1
35	4	0.09	1	5	7	7	2	9	0	5	1

Table A3 (continued).

36	4	0.08	1	4	7	7	0	3	0	4	1
36	4	0.13	1	5	7	7	0	9	0	4	1
37	2	8.38	1	4	7	7	1	3	0	4	1
37	2	1.32	1	3	7	7	0	3	0	4	1
37	2	1.22	1	2	1	1	0	6	0	4	1
37	4	0.04	1	4	7	7	0	3	0	4	1
37	4	0.01	1	4	7	7	0	2	0	4	1
37	4	0.04	1	4	7	7	0	1	0	4	1
38	3	0.07	1	1	1	1	0	2	0	4	1
38	4	0.05	1	4	7	7	0	2	0	4	1
38	4	0.01	1	4	7	7	0	2	0	4	1
38	4	0.05	1	1	1	1	0	2	0	4	1
38	4	0.03	1	1	4	0	0	2	0	4	1
38	4	0.01	1	1	4	0	0	1	0	4	1
38	4	0.01	1	6	7	7	0	1	0	4	1
39	2	2.39	1	2	1	2	4	1	0	4	1
39	3	0.34	1	1	3	1	0	2	0	4	1
39	4	0.03	1	4	7	7	5	0	0	4	1
39	4	0.04	1	4	7	7	5	0	0	4	1
40	2	7.32	1	4	7	7	4	3	0	4	1
41	3	0.63	1	1	1	2	0	4	0	2	1
41	4	0.07	1	4	7	7	0	3	0	2	1
42	3	0.34	1	1	4	1	0	3	0	4	1
43	4	0.14	1	1	4	1	1	2	0	4	1
44	2	1.15	1	1	3	3	0	3	0	4	1
45	2	9.75	1	5	7	7	4	9	0	4	1
46	2	1.99	1	1	4	3	1	4	0	2	1
47	3	0.69	1	1	4	1	0	3	0	2	1
48	3	0.63	1	2	3	1	0	3	0	4	1
48	3	0.15	1	4	7	7	0	2	0	4	1
49	2	2.48	1	1	1	2	0	4	0	2	1
50	4	0.02	1	1	3	2	0	2	0	5	1
51	2	3.15	1	1	3	4	0	4	0	2	1
52	4	0.01	1	1	3	1	0	2	0	5	1
53	2	2.28	1	4	7	7	0	4	0	2	1
53	4	0.03	1	4	7	7	0	2	0	2	1
53	4	0.02	1	4	7	7	0	2	0	2	1
54	4	0.01	1	1	3	1	0	2	0	4	1
54	3	0.06	1	4	7	7	0	1	0	4	1
55	2	1.93	1	1	3	2	0	2	0	2	1
56	4	0.01	1	4	7	7	0	4	0	4	1
56	4	0.01	1	4	7	7	0	2	0	4	1

Table A3 (continued).

57	2	3.54	1	1	3	3	0	6	0	2	1
57	4	0.04	1	4	7	7	0	2	0	2	1
58	4	0.04	1	1	1	1	0	2	0	5	1
59	3	1.37	1	2	3	2	1	5	0	2	1
59	4	0.12	1	4	7	7	0	9	0	2	1
60	4	0.11	1	1	3	2	1	2	0	4	1
61	3	0.41	1	4	7	7	1	3	0	4	1
61	4	0.06	1	3	7	7	1	1	0	4	1
61	4	0.06	1	3	7	7	2	1	0	4	1
61	4	0.03	1	3	7	7	2	1	0	4	1
61	4	0.02	1	3	7	7	0	1	0	4	1
62	4	0.03	1	4	7	7	1	1	0	4	1
63	3	0.24	1	1	1	1	2	1	0	4	1
63	4	0.13	1	4	7	7	0	2	0	4	1
64	3	0.87	1	1	4	1	0	4	0	2	1
64	4	0.01	1	4	7	7	0	3	0	2	1
64	4	0.05	1	4	1	1	0	3	0	2	1
65	3	0.64	1	2	3	2	0	5	0	4	1
65	4	0.01	1	4	7	7	0	2	0	4	1
65	4	0.05	1	4	7	7	0	2	0	4	1
66	4	0.06	1	1	1	1	0	3	0	4	1
67	3	0.37	1	5	7	7	2	9	0	4	1
67	3	0.21	1	1	1	2	2	1	0	4	1
68	4	0.05	1	1	1	1	0	2	0	4	1
69	4	0.01	1	1	3	1	0	2	0	4	1
70	4	0.19	1	1	1	2	0	1	0	4	1
71	4	0.02	1	1	1	2	0	3	0	4	1
72	4	0.05	1	4	7	7	0	2	0	4	1
72	4	0.01	1	4	7	7	0	2	0	4	1
73	3	0.66	1	1	1	1	0	6	0	4	1
74	3	0.63	1	1	1	1	0	6	0	4	1
75	3	0.16	1	4	7	7	0	3	0	4	1
75	4	0.02	1	2	1	2	0	2	0	4	1
76	3	0.33	1	4	7	7	0	3	0	4	1
76	4	0.10	1	5	7	7	0	9	0	4	1
77	3	0.12	1	1	1	2	0	3	0	4	1
77	4	0.03	1	4	7	7	0	2	0	4	1
78	4	0.02	1	1	1	1	0	2	0	4	1
79	4	0.15	1	2	3	2	0	4	0	4	1
80	3	0.18	1	4	7	7	0	3	0	2	1
80	4	0.11	1	2	3	3	0	2	0	2	1
81	3	0.15	1	1	3	2	1	3	0	2	1

Table A3 (continued).

82	3	0.19	1	2	3	2	0	4	0	2	1
83	4	0.03	1	3	7	7	0	2	0	4	1
83	4	0.02	1	3	7	7	0	3	0	4	1
84	3	0.21	1	1	1	2	0	4	0	4	1
85	3	0.28	1	1	1	1	0	2	0	2	1
85	4	0.12	1	5	7	7	0	9	0	2	1
86	4	0.06	1	3	7	7	0	2	0	4	1
87	4	0.03	1	4	7	7	0	2	0	4	1
88	2	2.30	1	1	3	2	0	5	0	2	1
89	4	0.01	1	4	7	7	0	1	0	5	1
90	4	0.05	1	4	7	7	0	3	0	5	1
90	4	0.01	1	2	1	1	0	3	0	5	1
90	4	0.01	1	2	1	1	0	2	0	5	1
90	4	0.04	1	4	7	7	0	3	0	5	1
90	4	0.01	1	3	7	7	0	2	0	5	1
91	3	0.16	1	1	3	2	0	2	0	2	1
92	4	0.03	1	5	7	7	1	9	0	5	1
93	3	0.36	1	1	3	3	0	3	0	4	1
94	2	4.05	1	1	3	4	0	4	0	2	1
95	4	0.01	1	5	7	7	0	9	0	6	1
96	2	0.86	1	4	7	7	4	2	0	2	1
97	4	0.07	1	1	3	1	0	3	0	2	1
98	4	0.08	1	4	7	7	1	2	0	4	2
98	4	0.03	1	3	7	7	1	2	0	4	1
98	4	0.03	1	2	1	1	0	2	0	4	1
99	4	0.06	1	2	1	2	0	3	0	4	1
99	4	0.01	1	4	7	7	0	3	0	4	1
100	4	0.01	1	4	7	7	0	1	0	4	1
101	4	0.07	1	1	1	1	0	2	0	4	1
102	3	0.12	1	1	1	1	0	3	0	4	1
102	4	0.04	1	1	1	1	0	4	0	4	1
103	4	0.03	1	4	7	7	0	3	0	6	3
104	4	0.05	1	6	7	7	0	9	0	6	3
104	4	0.04	1	6	7	7	0	9	0	6	3
104	4	0.02	1	1	1	1	0	3	0	6	3
105	4	0.01	1	1	1	3	0	2	0	6	3
106	4	0.03	1	1	1	2	0	3	0	6	3
107	4	0.03	1	3	7	7	0	3	0	6	3
107	4	0.07	1	2	1	1	0	4	0	6	3
108	4	0.03	1	2	1	3	0	2	0	6	3
108	4	0.02	1	4	7	7	0	4	0	6	3
109	4	0.02	1	2	3	3	0	2	0	6	3

Table A3 (continued).

110	4	0.03	1	4	7	7	0	3	0	6	3
110	4	0.04	1	2	3	1	0	3	0	6	3
111	4	0.01	1	6	7	7	0	3	0	6	3
111	4	0.01	1	6	7	7	0	3	0	6	3
112	4	0.03	1	3	7	7	0	9	0	6	3
113	4	0.08	1	1	3	2	0	4	0	6	3
114	4	0.06	1	1	3	2	0	2	0	6	3
115	4	0.06	1	2	3	2	0	4	0	6	3
115	4	0.01	1	4	7	7	0	3	0	6	3
116	4	0.01	1	1	1	1	0	3	0	6	3
117	4	0.01	1	1	3	1	0	4	0	6	3
118	4	0.03	1	1	3	1	0	2	0	6	3
119	4	0.01	1	2	1	2	0	2	0	6	3
120	4	0.01	1	1	3	1	0	1	0	6	3
121	4	0.03	1	1	3	2	0	2	0	6	3
122	4	0.01	1	1	1	1	0	2	0	5	1
123	4	0.06	1	1	3	2	0	3	0	6	3
124	4	0.06	1	1	3	1	0	3	0	6	3
125	4	0.07	1	2	3	3	0	3	0	6	3
126	4	0.01	1	3	7	7	0	3	0	6	3
127	4	0.05	1	1	3	1	2	3	0	6	3
128	3	0.22	1	1	3	2	1	4	0	6	3
129	4	0.04	1	3	7	7	0	2	0	6	3
130	4	0.06	1	1	3	2	1	3	0	6	3
131	4	0.06	1	1	3	3	1	3	0	6	3
132	4	0.04	1	1	3	1	2	3	0	6	3
133	4	0.06	1	1	3	2	2	2	0	6	3
134	4	0.06	1	1	3	3	0	3	0	6	3
135	4	0.10	1	1	3	1	0	2	0	6	3
136	4	0.05	1	2	3	2	0	4	0	6	3
137	4	0.06	1	4	7	7	0	3	0	6	3
137	4	0.02	1	6	7	7	0	9	0	6	3
137	4	0.02	1	6	7	7	1	9	0	6	3
139	3	0.10	1	3	7	7	0	5	0	2	3
139	4	0.05	1	3	7	7	1	1	0	2	3
140	4	0.03	1	2	3	1	0	3	0	2	3
140	4	0.05	1	4	7	7	0	4	0	2	3
141	4	0.08	1	4	7	7	0	5	0	2	3
141	4	0.03	1	2	3	1	0	2	0	2	3
142	4	0.01	1	1	3	1	0	3	0	6	3
143	4	0.09	1	1	3	1	0	3	0	2	3
143	4	0.03	1	5	7	7	4	9	0	2	3

Table A3 (continued).

144	4	0.01	1	4	7	7	0	3	0	6	3
145	4	0.06	1	2	3	2	0	2	0	2	3
145	3	0.10	1	3	7	7	0	5	0	2	3
145	4	0.05	1	4	7	7	0	4	0	2	3
146	4	0.05	1	1	3	1	0	3	0	6	3
147	4	0.05	1	1	3	2	0	4	0	6	3
148	4	0.01	1	1	1	2	0	2	0	6	3
149	4	0.05	1	2	3	3	0	3	0	6	3
149	4	0.02	1	4	7	7	1	2	0	6	3
150	4	0.09	1	1	3	2	0	3	0	6	3
151	4	0.04	1	1	3	1	0	2	0	6	3
152	4	0.05	1	2	1	1	1	3	0	6	3
152	4	0.01	1	4	7	7	2	2	0	6	3
153	4	0.04	1	1	3	2	0	2	0	6	3
154	3	0.09	1	4	7	7	2	2	0	2	3
154	4	0.07	1	2	3	1	0	2	0	2	3
155	3	0.08	1	1	3	2	1	2	0	6	3
156	3	0.17	1	6	7	7	1	2	0	6	3
156	4	0.01	1	4	7	7	0	1	0	6	3
157	4	0.10	1	2	3	2	0	3	0	6	3
158	4	0.04	1	6	7	7	0	1	0	6	3
158	4	0.03	1	6	7	7	0	2	0	6	3
159	4	0.03	1	1	3	3	0	1	0	6	3
160	4	0.05	1	1	3	1	0	2	0	6	3
161	4	0.05	1	1	1	2	0	3	0	6	3
162	4	0.12	1	1	3	4	0	3	0	6	3
163	4	0.01	1	4	7	7	0	2	0	6	3
163	4	0.02	1	3	7	7	0	2	0	6	3
163	4	0.03	1	3	7	7	0	3	0	6	3
164	4	0.06	1	1	1	3	0	2	0	6	3
165	4	0.01	1	3	7	7	0	2	0	6	3
165	3	0.12	1	2	3	2	0	3	0	6	3
165	4	0.01	1	4	7	7	0	1	0	6	3
166	4	0.03	1	2	3	1	0	2	0	6	3
166	4	0.03	1	4	7	7	0	1	0	6	3
167	4	0.05	1	1	3	1	0	3	0	6	3
168	4	0.04	1	2	3	2	0	3	0	6	3
169	4	0.03	1	4	7	7	0	3	0	6	3
170	4	0.02	1	1	3	2	0	2	0	6	3
171	4	0.07	1	4	7	7	0	4	0	6	3
171	4	0.10	1	2	3	2	0	4	0	6	3
171	4	0.03	1	3	7	7	0	2	0	6	3

Table A3 (continued).

171	4	0.01	1	3	7	7	0	1	0	6	3
171	4	0.05	1	1	3	1	0	5	0	6	3
173	4	0.09	1	1	3	2	0	3	0	6	3
174	4	0.07	1	2	3	2	0	3	0	6	3
174	4	0.01	1	4	7	7	0	2	0	6	3
175	4	0.04	1	1	3	2	0	3	0	6	3
176	4	0.11	1	2	3	1	0	3	0	6	3
176	4	0.01	1	2	3	2	0	2	0	6	3
177	4	0.03	1	5	7	7	0	9	0	6	3
177	4	0.01	1	5	7	7	0	9	0	6	3
178	4	0.15	1	1	3	1	0	6	0	6	3
179	4	0.07	1	2	3	1	0	3	0	6	3
179	4	0.02	1	4	7	7	0	3	0	6	3
180	4	0.01	1	1	3	1	0	3	0	6	3
181	4	0.04	1	1	3	2	0	4	0	6	3
182	4	0.01	1	1	3	1	0	3	0	6	3
182	4	0.02	1	1	3	1	0	3	0	6	3
183	4	0.01	1	2	3	2	0	2	0	6	3
184	4	0.03	1	1	3	3	0	2	0	6	3
185	4	0.01	1	1	3	2	0	3	0	6	3
186	4	0.01	1	4	7	7	0	3	0	6	3
187	4	0.05	1	1	3	2	0	3	0	6	3
188	4	0.01	1	2	3	1	0	2	0	6	3
189	4	0.05	1	1	3	2	0	4	0	6	3
190	4	0.01	1	4	7	7	0	2	0	6	3
190	4	0.09	1	2	3	2	0	4	0	6	3
191	4	0.04	1	1	1	2	0	3	0	6	3
192	4	0.03	1	4	7	7	0	4	0	6	3
192	4	0.08	1	2	3	2	0	4	0	6	3
193	4	0.06	1	2	3	2	0	4	0	6	3
193	4	0.02	1	4	7	7	0	2	0	6	3
194	3	0.17	1	1	3	1	0	4	0	6	3
195	4	0.14	1	1	3	3	0	4	0	6	3
196	4	0.05	1	1	3	2	0	3	0	6	3
197	4	0.09	1	1	3	2	0	3	0	6	3
198	3	0.14	1	4	7	7	0	5	0	6	3
198	4	0.04	1	2	3	3	0	3	0	6	3
199	4	0.02	1	4	7	7	0	2	0	6	3
200	4	0.02	1	3	7	7	0	2	0	6	3
200	4	0.03	1	3	7	7	0	2	0	6	3
200	4	0.04	1	3	7	7	0	2	0	6	3
200	4	0.03	1	4	7	7	0	2	0	6	3

Table A3 (continued).

201	4	0.05	1	1	3	2	0	3	0	6	3
202	4	0.01	1	4	7	7	0	2	0	6	3
202	4	0.06	1	3	7	7	1	3	0	6	3
203	4	0.01	1	4	7	7	0	2	0	6	3
203	4	0.04	1	1	3	1	0	2	0	6	3
204	4	0.01	1	1	3	2	0	3	0	6	3
205	4	0.04	1	4	7	7	0	3	0	6	3
206	4	0.02	1	1	3	1	0	2	0	6	3
207	4	0.01	1	4	7	7	0	2	0	6	3
207	4	0.02	1	3	7	7	0	2	0	6	3
208	4	0.01	1	1	1	1	0	2	0	6	3
209	4	0.01	1	4	7	7	0	2	0	3	3
209	4	0.05	1	2	3	1	0	5	0	3	3
210	4	0.01	1	1	3	1	0	3	0	3	3
211	4	0.01	1	1	1	1	0	3	0	3	3
212	4	0.02	1	1	3	2	0	2	0	3	3
213	4	0.02	1	1	3	3	0	2	0	3	3
214	4	0.01	1	1	1	3	0	2	0	3	3
215	4	0.01	1	1	3	1	0	1	0	3	3
216	4	0.01	1	1	3	4	0	2	0	3	3
217	4	0.01	1	1	3	3	0	4	0	3	3
218	4	0.01	1	1	3	2	0	4	0	3	3
219	4	0.01	1	1	1	2	0	3	0	3	3
220	4	0.01	1	4	7	7	0	4	0	3	3
221	4	0.01	1	1	3	2	0	3	0	3	3
222	4	0.01	1	1	3	2	0	2	0	3	3
223	4	0.01	1	1	3	2	0	3	0	3	3

Table A4.

Experiment 30 Flake Attributes

Flake #	SG	WT	RM	PO	PL	F	CO	DS	MO	RD	PT
1	2	6.65	1	1	4	0	5	0	0	4	1
1	3	0.08	1	5	7	7	0	9	0	4	1
1	4	0.01	1	4	7	7	5	0	0	4	1
1	4	0.28	1	5	7	7	3	9	0	4	1
2	3	0.02	1	1	4	0	0	1	0	5	1
3	2	30.79	1	1	4	0	4	2	0	4	1
4	3	0.49	1	5	7	7	1	9	0	4	1

Table A4 (continued).

4	3	1.17	1	2	4	0	1	1	0	4	1
4	4	0.10	1	4	7	7	2	4	0	4	1
4	4	0.02	1	4	7	7	0	2	0	4	1
4	4	0.01	1	4	7	7	0	1	0	4	1
5	4	0.02	1	1	4	0	0	2	0	5	1
6	4	0.20	1	1	2	0	3	1	0	4	1
7	4	0.17	1	4	7	7	4	1	0	4	1
8	3	0.24	1	1	3	1	5	0	0	4	1
9	3	1.69	1	1	3	2	5	0	0	4	1
10	2	3.31	1	1	3	1	4	4	0	4	1
11	3	0.63	1	1	3	2	3	1	0	4	1
12	4	0.06	1	4	7	7	4	1	0	4	1
13	3	0.85	1	1	3	1	4	1	0	4	1
14	4	0.03	1	4	7	7	1	2	0	4	1
15	2	1.32	1	1	3	2	1	4	0	4	1
16	4	0.03	1	4	7	7	2	1	0	4	1
17	3	0.21	1	2	1	1	2	2	0	4	1
17	4	0.01	1	4	7	7	3	1	0	4	1
18	1	13.20	1	1	4	0	1	6	0	4	1
19	4	0.01	1	1	4	0	0	3	0	5	1
20	4	0.01	1	1	4	0	0	2	0	6	3
21	4	0.03	1	1	4	0	0	2	0	6	3
23	4	0.02	1	1	4	0	0	2	0	6	3
24	4	0.03	1	1	4	0	0	2	0	6	3
25	4	0.08	1	1	4	0	0	2	0	6	3
26	4	0.13	1	1	4	0	0	4	0	6	3
27	4	0.01	1	4	7	7	0	1	0	6	3
28	4	0.02	1	6	7	7	0	3	0	6	3
29	4	0.01	1	2	3	2	0	1	0	6	3
30	4	0.01	1	2	4	0	0	2	0	6	3
31	4	0.01	1	4	7	7	5	7	0	6	3
32	4	0.01	1	1	3	2	5	0	0	6	3
33	4	0.04	1	2	3	2	3	3	0	6	3
34	4	0.04	1	2	4	0	0	3	0	6	3
35	4	0.08	1	2	3	2	2	1	0	6	3
36	4	0.03	1	2	4	0	0	2	0	6	3
37	4	0.01	1	4	7	7	0	3	0	6	3
37	4	0.01	1	2	4	0	0	2	0	6	3
38	4	0.02	1	1	4	0	0	2	0	6	3
39	4	0.02	1	4	7	7	3	1	0	6	3
40	4	0.02	1	2	3	2	0	2	0	6	3
41	4	0.03	1	2	3	1	0	2	0	6	3

Table A4 (continued).

42	4	0.09	1	2	3	2	2	1	0	6	3
43	4	0.06	1	2	4	1	0	3	0	6	3
44	4	0.01	1	1	1	2	0	3	0	6	3
45	4	0.03	1	6	7	7	0	2	0	6	3
46	4	0.05	1	1	4	1	0	2	0	6	3
47	4	0.03	1	1	3	2	4	1	0	6	3
48	4	0.01	1	2	4	0	0	2	0	6	3
49	4	0.02	1	2	4	0	0	3	0	6	3
49	4	0.01	1	4	7	7	0	2	0	6	3
50	4	0.01	1	1	3	2	5	0	0	6	3
51	4	0.01	1	1	3	1	5	0	0	6	3
52	4	0.06	1	2	3	1	1	1	0	6	3
52	4	0.01	1	4	7	7	5	0	0	6	3
53	3	0.11	1	2	4	0	0	5	0	6	3
53	4	0.01	1	4	7	7	0	2	0	6	3
54	4	0.04	1	1	4	0	0	2	0	6	3
55	4	0.16	1	1	3	1	0	4	0	6	3
56	4	0.02	1	2	3	1	0	2	0	6	3
57	4	0.01	1	1	3	1	3	1	0	6	3
58	4	0.01	1	1	4	1	0	2	0	6	3
59	4	0.02	1	1	3	1	0	2	0	6	3
60	4	0.03	1	2	3	1	0	2	0	6	3
60	4	0.03	1	4	7	7	0	2	0	6	3
61	4	0.07	1	2	3	1	0	3	0	6	3
61	4	0.01	1	4	7	7	0	2	0	6	3
62	4	0.01	1	2	3	1	0	3	0	6	3
62	4	0.01	1	3	7	7	0	2	0	6	3
62	4	0.01	1	4	7	7	0	2	0	6	3
63	4	0.02	1	2	3	1	0	2	0	6	3
63	4	0.01	1	4	7	7	0	2	0	6	3
64	4	0.06	1	2	3	1	0	3	0	6	3
64	4	0.01	1	4	7	7	0	2	0	6	3
65	4	0.07	1	1	4	0	0	4	0	6	3
66	4	0.03	1	2	3	2	0	2	0	6	3
66	4	0.04	1	4	7	7	0	3	0	6	3
67	4	0.07	1	1	4	2	0	3	0	6	3
68	4	0.03	1	4	7	7	0	2	0	6	3
69	4	0.11	1	2	4	0	0	4	0	6	3
70	4	0.06	1	2	4	0	0	2	0	6	3
71	4	0.05	1	1	4	0	0	4	0	6	3
72	4	0.02	1	2	2	1	0	1	0	6	3
73	4	0.01	1	2	3	1	0	2	0	6	3

Table A4 (continued).

74	4	0.02	1	1	3	2	0	2	0	6	3
75	4	0.05	1	2	3	2	0	3	0	4	2
76	4	0.07	1	3	7	7	0	3	0	4	1
76	4	0.04	1	3	7	7	0	2	0	4	1
77	4	0.01	1	2	1	1	0	2	0	5	1
78	3	0.27	1	2	1	2	0	5	0	4	1
79	4	0.07	1	2	3	2	3	2	0	6	3
79	4	0.02	1	4	7	7	3	1	0	6	3
79	4	0.01	1	4	7	7	4	2	0	6	3
80	4	0.03	1	2	3	1	1	2	0	6	3
80	4	0.04	1	4	7	7	2	2	0	6	3
81	4	0.02	1	4	7	7	4	1	0	6	3
81	4	0.02	1	3	7	7	4	1	0	6	3
82	4	0.01	1	3	7	7	2	1	0	6	3
83	4	0.04	1	1	3	1	2	3	0	6	3
84	4	0.04	1	2	3	1	5	0	0	6	3
85	4	0.03	1	2	3	1	4	1	0	6	3
85	4	0.01	1	4	7	7	5	0	0	6	3
86	4	0.04	1	1	3	1	5	0	0	6	3
87	4	0.09	1	1	3	1	3	2	0	6	3
88	4	0.05	1	1	1	1	0	3	0	6	3
89	4	0.01	1	4	7	7	0	9	0	6	3
90	4	0.02	1	1	3	1	0	2	0	6	3
91	4	0.01	1	1	3	1	0	2	0	6	3
92	4	0.04	1	1	3	1	2	3	0	6	3
93	4	0.01	1	1	1	1	0	2	0	6	3
93	4	0.01	1	1	3	1	0	3	0	6	3
94	4	0.18	1	1	3	3	0	5	0	6	3
95	4	0.04	1	1	1	1	0	3	0	6	3
96	4	0.12	1	1	1	1	0	4	0	4	1
97	4	0.05	1	1	3	1	0	3	0	6	3
98	4	0.06	1	1	3	3	0	2	0	6	3
99	4	0.09	1	1	3	2	0	2	0	6	3
100	4	0.04	1	1	3	2	0	2	0	6	3
101	4	0.01	1	1	1	1	1	2	0	6	3
102	4	0.01	1	1	3	1	0	2	0	6	3
103	4	0.01	1	2	3	1	0	2	0	6	3
104	4	0.02	1	2	1	1	0	2	0	6	3
104	4	0.03	1	3	7	7	0	1	0	6	3
104	4	0.09	1	4	7	7	0	3	0	6	3
105	4	0.01	1	2	3	1	0	2	0	6	3
105	4	0.01	1	4	7	7	0	1	0	6	3

Table A4 (continued).

106	4	0.01	1	4	7	7	0	3	0	6	3
106	4	0.03	1	2	3	2	0	3	0	6	3
107	4	0.02	1	3	7	7	0	2	0	6	3
107	4	0.04	1	4	7	7	0	5	0	6	3
108	3	0.08	1	1	3	2	1	3	0	6	3
109	4	0.03	1	1	3	2	2	2	0	6	3
110	4	0.05	1	1	3	2	0	3	0	6	3
111	4	0.01	1	4	7	7	0	2	0	6	3
112	4	0.02	1	1	3	2	0	2	0	3	3
112	4	0.01	1	4	7	7	0	2	0	3	3
112	4	0.02	1	4	7	7	4	2	0	3	3
112	4	0.04	1	1	3	2	0	2	0	3	3
113	4	0.01	1	4	7	7	0	3	0	3	3
114	4	0.10	1	1	2	0	0	3	0	3	3
115	4	0.01	1	2	3	1	0	3	0	3	3
115	4	0.01	1	4	7	7	0	2	0	3	3
116	4	0.01	1	1	3	2	0	3	0	3	3
117	4	0.04	1	1	3	2	0	3	0	3	3
118	4	0.02	1	2	3	1	0	3	0	3	3
119	4	0.05	1	1	3	2	4	1	0	3	3
120	4	0.04	1	1	1	1	0	4	0	3	3
121	4	0.02	1	1	1	2	0	3	0	3	3
122	4	0.06	1	1	3	3	0	3	0	3	3
123	4	0.01	1	4	7	7	0	2	0	3	3
123	4	0.03	1	2	3	2	0	2	0	3	3
124	4	0.02	1	1	3	2	0	2	0	3	3
125	4	0.01	1	1	3	1	0	3	0	3	3
126	4	0.01	1	1	1	2	0	2	0	3	3
127	4	0.05	1	1	1	1	0	3	0	3	3
128	4	0.09	1	2	3	3	4	1	0	3	3
129	4	0.05	1	1	3	1	0	3	0	3	3
130	4	0.01	1	1	3	2	0	2	0	3	3
131	4	0.02	1	1	3	1	0	3	0	3	3
132	4	0.04	1	1	3	1	0	4	0	3	3
133	4	0.03	1	1	3	1	0	3	0	3	3

Table A5.

Experiment 33 Flake Attributes

Flake #	SG	WT	RM	PO	PL	F	CO	DS	MO	RD	PT
1	3	0.43	1	4	7	7	5	1	0	4	1
2	2	7.71	1	1	4	0	4	1	0	4	1
3	4	0.01	1	1	3	1	0	2	0	5	1
3	4	0.01	1	5	7	7	0	9	0	5	1
4	2	10.54	1	1	4	0	5	0	0	4	1
4	4	0.06	1	4	7	7	2	2	0	4	1
4	4	0.06	1	5	7	7	0	9	0	4	1
4	4	0.03	1	4	7	7	3	1	0	4	1
4	4	0.03	1	4	7	7	0	2	0	4	1
4	4	0.01	1	4	7	7	0	1	0	4	1
5	4	0.08	1	4	7	7	1	1	0	5	1
5	4	0.04	1	5	7	7	0	9	0	5	1
6	3	0.47	1	4	7	7	5	0	0	4	1
7	2	11.63	1	1	1	1	2	4	0	4	1
7	4	0.04	1	5	7	7	1	9	0	4	1
7	4	0.10	1	5	7	7	5	0	0	4	1
7	4	0.03	1	5	7	7	5	0	0	4	1
7	4	0.07	1	5	7	7	5	0	0	4	1
7	4	0.05	1	4	7	7	0	4	0	4	1
7	4	0.05	1	4	7	7	0	3	0	4	1
7	4	0.10	1	2	3	1	0	3	0	4	1
7	4	0.06	1	5	7	7	1	9	0	4	1
8	3	0.10	1	1	1	1	0	4	0	5	1
8	4	0.04	1	1	3	1	0	2	0	5	1
8	4	0.03	1	1	3	1	0	2	0	5	1
8	4	0.05	1	1	3	1	0	3	0	5	1
8	4	0.01	1	1	1	1	0	3	0	5	1
8	4	0.04	1	1	3	1	0	3	0	5	1
8	4	0.04	1	4	7	7	0	4	0	5	1
8	4	0.04	1	1	3	1	0	2	0	5	1
8	4	0.02	1	1	4	0	0	3	0	5	1
8	4	0.01	1	1	3	1	0	2	0	5	1
8	4	0.02	1	1	3	1	0	2	0	5	1
9	3	0.57	1	1	1	1	0	1	0	4	1
10	2	2.29	1	2	3	1	2	3	0	4	2
10	3	1.98	1	4	7	7	3	3	0	4	2
10	3	0.14	1	4	7	7	0	1	0	4	2
10	3	0.08	1	2	3	1	0	1	0	4	2

Table A5 (continued).

10	4	0.03	1	1	3	1	1	2	0	4	2
10	4	0.08	1	4	7	7	3	1	0	4	2
10	4	0.01	1	2	3	1	0	2	0	4	2
10	4	0.03	1	4	7	7	0	3	0	4	2
11	3	3.21	1	1	3	2	0	6	0	4	2
12	4	0.02	1	1	3	1	0	4	0	5	2
13	4	0.05	1	1	3	1	1	2	0	5	1
14	2	2.47	1	1	4	1	1	3	0	4	2
15	3	0.14	1	2	3	2	1	2	0	4	2
15	3	0.14	1	4	7	7	4	1	0	4	2
15	4	0.03	1	3	7	7	4	1	0	4	2
15	4	0.01	1	1	3	1	0	2	0	4	2
15	4	0.09	1	4	7	7	2	1	0	4	2
16	2	20.91	1	1	2	0	4	2	0	4	2
16	4	0.04	1	5	7	7	1	9	0	4	2
17	4	0.02	1	1	1	1	2	2	0	4	1
17	4	0.04	1	1	3	2	0	1	0	4	1
18	2	7.82	1	1	2	0	1	6	0	4	1
18	4	0.03	1	1	3	1	5	0	0	4	1
18	4	0.03	1	4	7	7	2	1	0	4	1
19	3	0.52	1	2	4	1	0	4	0	4	2
19	4	0.04	1	4	7	7	0	1	0	4	2
19	4	0.04	1	4	7	7	0	2	0	4	2
19	4	0.02	1	5	7	7	0	9	0	4	2
19	4	0.04	1	5	7	7	0	9	0	4	2
20	3	3.95	1	3	7	7	4	4	0	4	2
20	3	1.14	1	4	7	7	1	2	0	4	2
20	4	0.09	1	2	3	2	4	1	0	4	2
20	4	0.06	1	4	7	7	0	2	0	4	2
20	4	0.07	1	4	7	7	0	3	0	4	2
21	3	0.13	1	1	1	1	0	3	0	4	1
22	4	0.05	1	5	7	7	0	9	0	5	1
23	2	3.95	1	1	3	3	2	2	0	2	2
23	4	0.12	1	4	7	7	0	1	0	2	2
23	4	0.01	1	4	7	7	1	2	0	2	2
23	4	0.01	1	4	7	7	4	1	0	2	2
24	2	1.83	1	2	4	2	1	3	0	2	2
24	4	0.01	1	4	7	7	0	1	0	2	2
25	3	0.49	1	1	3	2	1	2	0	2	2
26	3	0.52	1	6	3	1	1	1	0	2	2
26	4	0.23	1	6	3	1	5	0	0	2	2
26	4	0.25	1	3	7	7	2	2	0	2	2

Table A5 (continued).

26	4	0.21	1	4	7	7	5	0	0	2	2
26	4	0.04	1	4	7	7	1	1	0	2	2
27	3	0.24	1	1	3	1	5	0	0	4	1
28	3	0.59	1	1	3	1	1	3	0	4	1
28	4	0.01	1	4	7	7	1	1	0	4	1
29	3	0.65	1	4	7	7	0	4	0	2	2
29	4	0.09	1	2	3	1	1	4	0	2	2
30	3	0.28	1	4	7	7	0	4	0	2	2
30	3	0.10	1	4	7	7	0	3	0	2	2
31	4	0.12	1	6	3	2	4	1	0	2	2
31	3	0.14	1	6	3	1	5	0	0	2	2
32	4	0.01	1	1	3	1	0	2	0	5	1
33	4	0.03	1	1	3	1	2	2	0	4	1
34	4	0.07	1	4	7	7	1	3	0	4	1
35	4	0.01	1	5	7	7	0	1	0	4	1
35	3	0.64	1	1	4	0	0	5	0	2	2
36	4	0.02	1	1	3	1	0	3	0	4	1
36	4	0.03	1	4	7	7	0	3	0	4	1
37	4	0.04	1	1	1	2	0	2	0	5	1
38	3	0.28	1	3	7	7	0	3	0	2	2
38	4	0.05	1	2	3	1	0	2	0	2	2
38	4	0.04	1	3	7	7	0	3	0	2	2
38	4	0.02	1	4	7	7	0	2	0	2	2
39	3	0.18	1	2	3	1	2	2	0	2	2
39	3	0.28	1	4	7	7	3	2	0	2	2
39	4	0.04	1	3	7	7	2	1	0	2	2
39	4	0.03	1	3	7	7	2	1	0	2	2
39	4	0.06	1	4	7	7	1	2	0	2	2
39	4	0.03	1	3	7	7	0	2	0	2	2
40	3	0.35	1	1	3	2	1	3	0	2	2
40	4	0.07	1	1	3	1	0	3	0	2	2
40	4	0.01	1	5	7	7	0	9	0	2	2
41	4	0.07	1	1	4	1	0	4	0	1	1
42	4	0.08	1	2	4	0	0	2	0	4	1
42	4	0.02	1	4	7	7	0	3	0	4	1
43	4	0.05	1	2	4	0	0	2	0	6	3
43	4	0.06	1	4	7	7	0	3	0	6	3
44	4	0.09	1	1	3	2	4	1	0	6	3
45	4	0.05	1	4	7	7	0	3	0	6	3
46	3	0.12	1	1	4	1	0	6	0	6	3
47	3	0.09	1	1	3	1	3	1	0	6	3
48	4	0.07	1	1	3	2	0	4	0	6	3

Table A5 (continued).

48	4	0.02	1	1	3	3	0	2	0	6	3
48	4	0.01	1	1	3	1	1	2	0	6	3
49	4	0.03	1	1	3	2	3	1	0	6	3
50	4	0.11	1	1	4	2	0	3	0	6	3
51	4	0.02	1	1	3	1	4	1	0	6	3
52	4	0.02	1	1	4	1	0	2	0	6	3
53	4	0.07	1	2	4	1	0	2	0	6	3
54	4	0.01	1	2	3	1	5	0	0	6	3
55	4	0.03	1	2	4	1	0	2	0	6	3
55	4	0.06	1	4	7	7	0	3	0	6	3
56	3	0.94	1	9							
57	4	0.02	1	2	3	1	0	3	0	6	3
57	4	0.11	1	4	7	7	0	4	0	6	3
58	4	0.07	1	2	3	2	0	4	0	6	3
58	4	0.01	1	3	7	7	0	3	0	6	3
59	4	0.01	1	4	7	7	0	2	0	5	1
60	4	0.03	1	2	3	2	0	2	0	6	3
61	4	0.02	1	2	3	3	0	3	0	6	3
61	4	0.03	1	3	7	7	0	4	0	6	3
61	4	0.01	1	4	7	7	0	2	0	6	3
62	4	0.12	1	1	3	1	0	6	0	6	3
63	4	0.10	1	1	3	2	0	3	0	6	3
64	3	0.24	1	2	3	1	0	3	0	6	3
64	4	0.03	1	4	7	7	0	3	0	6	3
64	4	0.01	1	4	7	7	0	4	0	6	3
65	4	0.03	1	1	3	1	0	2	0	6	3
66	4	0.12	1	1	3	3	0	3	0	6	3
67	4	0.06	1	1	4	0	0	5	0	6	3
68	4	0.03	1	2	3	2	0	3	0	6	3
68	4	0.04	1	4	7	7	0	3	0	6	3
69	4	0.06	1	1	3	2	1	3	0	6	3
70	4	0.05	1	2	4	0	0	3	0	6	3
70	4	0.01	1	4	7	7	0	2	0	6	3
71	4	0.02	1	2	3	2	0	2	0	6	3
71	4	0.01	1	4	7	7	0	3	0	6	3
72	4	0.02	1	2	3	2	0	2	0	6	3
73	4	0.08	1	1	3	2	0	4	0	6	3
74	4	0.03	1	1	3	2	1	2	0	6	3
75	4	0.01	1	1	3	2	0	3	0	6	3
76	4	0.04	1	1	1	2	1	3	0	6	3
77	4	0.03	1	1	3	2	0	3	0	6	3
78	4	0.03	1	1	3	1	0	4	0	6	3

Table A5 (continued).

79	4	0.07	1	2	3	1	0	4	0	6	3
79	4	0.04	1	4	7	7	0	4	0	6	3
80	4	0.04	1	2	3	1	1	4	0	6	3
81	4	0.03	1	5	7	7	1	9	0	6	3
81	4	0.05	1	4	7	7	2	2	0	6	3
82	3	0.19	1	2	3	2	1	4	0	6	3
82	4	0.06	1	4	7	7	2	2	0	6	3
83	4	0.01	1	1	3	1	4	1	0	6	3
84	4	0.01	1	1	1	2	3	2	0	6	3
85	4	0.01	1	1	3	2	0	2	0	6	3
86	4	0.02	1	2	3	2	1	2	0	6	3
86	4	0.01	1	4	7	7	4	1	0	6	3
87	4	0.03	1	1	3	2	0	3	0	6	3
88	4	0.05	1	1	3	1	0	3	0	6	3
89	4	0.05	1	1	3	1	0	4	0	6	3
90	4	0.03	1	2	1	1	0	3	0	6	3
90	4	0.04	1	3	7	7	0	2	0	6	3
90	4	0.02	1	4	7	7	2	1	0	6	3
91	3	0.11	1	2	3	2	0	4	0	6	3
91	4	0.02	1	4	7	7	0	4	0	6	3
92	4	0.09	1	2	3	1	0	4	0	6	3
92	4	0.03	1	4	7	7	0	2	0	6	3
93	4	0.07	1	2	3	1	0	2	0	6	3
93	4	0.01	1	4	7	7	0	4	0	6	3
94	4	0.07	1	2	3	2	0	2	0	6	3
94	4	0.01	1	4	7	7	0	2	0	6	3
95	4	0.02	1	1	4	1	0	3	0	6	3
96	4	0.09	1	6	7	7	0	4	0	6	3
96	4	0.19	1	6	7	7	1	2	0	6	3
96	4	0.01	1	4	7	7	1	3	0	6	3

Note: Event 56 resulted in the fracture of the distal tip.

APPENDIX C – Permission to Use Figures

Gmail

Ronald Wise Jr <ronald.wise.jr@gmail.com>

Permission for use of figure

1 message

Andrew Bradbury <apbradbury@crai-ky.com> Thu, Jun 30, 2016 at 12:03 PM

To: Ronald Wise Jr <ronald.wise.jr@gmail.com>

Ronald,

Glad to hear that you are finishing up your thesis. Concerning the use of the model of the organization of technology figure from the paper by Phil Carr, Sarah Price and myself (2012), you have my permission to reproduce the figure in your thesis. If you need anything further, please feel free to contact me.

Andrew Bradbury

APPENDIX D – Eigenvalue Report

Table A6.

Eigenvalue Report for Correspondence Analysis of Flake Attributes

	Eigenvalues	% of Variance	Cumulative % of Variance
Dimension 1	0.19775537	91.588142	91.58814
Dimension 2	0.01816272	8.411858	100.00000

Table A7.

Correspondence Analysis Column Values

Column	Dimension 1 Coordinate	Dimension 2 Coordinate	Dimension 1 % Contribution	Dimension 2 % Contribution
SG1	1.360133835	-0.468831945	1.118996e+00	1.447595284
SG2	1.144819036	0.119051437	1.426959e+01	1.680175164
SG3	0.684181362	0.352923778	1.132577e+01	32.812143355
SG4	-0.384393620	-0.113722058	1.292963e+01	12.321700977
F0	0.638783595	-0.223087926	9.214456e+00	12.236625527
F1	-0.006879361	0.041271811	2.442758e-03	0.957278979
F2	-0.345851487	0.043808402	4.799285e+00	0.838415719
F3	-0.474630937	0.117203825	1.862259e+00	1.236399852
F4	-0.031333985	0.405133927	7.918363e-04	1.441281240
DS0	0.669558848	-0.289702922	2.169366e+00	4.421895816
DS1	0.545765054	-0.246791247	4.564248e+00	10.161658907
DS2	-0.047890498	0.006332386	1.035836e-01	0.019718521
DS3	-0.372325948	0.018955104	4.779549e+00	0.134877636
DS4	-0.155989064	0.129649468	3.728602e-01	2.804442775
DS5	-0.063631204	0.493316435	1.469457e-02	9.616459072
DS6	0.481312054	0.083146501	8.874650e-01	0.288358707
CO_No	-0.346508619	0.055233367	8.424643e+00	2.330632508
CO_Plat	0.506612795	-0.131909075	6.986027e+00	5.156732880
CO_Dor	0.420756935	-0.004167742	5.568412e+00	0.005948642
CO_PlatDor	1.176549638	0.032415992	1.060592e+01	0.087658439

Table A8.

Correspondence Analysis Row Values

Row	Dimension 1 Coordinate	Dimension 2 Coordinate	Dimension 1 % Contribution	Dimension 2 % Contribution
1	0.60484736	-0.06318408	60.2639804	7.160262
2	0.08779826	0.36465004	0.4662698	87.572008
3	-0.37419107	-0.04153387	39.2697498	5.267730

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