“A TALE OF TWO WEAPONS”:

LATE HOLOCENE HUNTING TECHNOLOGY IN NORTH CENTRAL TEXAS

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This research is an investigation of the Late Holocene technological transition from the spearthrower and dart to the bow and arrow in north central Texas. It is conducted through a theoretical approach that utilizes ethnographic research, experimental archaeology and the archaeological record to elucidate differences in the behaviors and hunting strategies of Late Archaic and Late Prehistoric groups. It first confirms that there was a transition. Second, a lithic analysis demonstrates that there are fundamental differences in the sizes of the stone dart and arrow points that relate to the propulsive requirements of the weapon systems. Third, it is shown these size differences constrain maintenance potentials and that indeed dart and arrow points exhibit stark differences in their life histories in spite of being employed for the same task. And finally, the faunal record suggests that this transition was associated with an increase in foraging efficiency.

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CHAPTER 1

INTRODUCTION

The Late Holocene (4500-1250 bp) in north-central Texas was a period in which it is often assumed that there was a major technological transition from the atlatl (spearthrower and dart) to the bow and arrow. This was diachronic global phenomenon that is significant for three main reasons. 1) The atlatl had been used for thousands of years in the Old World and New World. 2) It was employed in basically all ecological zones inhabited. 3) All native groups from hunter-gatherers to complex societies such as the Aztecs and the Toltec-Maya employed the weapon. With the exception of a few cultures worldwide there was a virtual replacement of the weapon by the bow and arrow across all ecological zones and within all types of sociocultural groups. One could logically surmise that there was some type of advantage with the new technology.

The archaeological record in north-central Texas indicates that the change to the bow and arrow technology occurred at approximately 1250 BP. Inhabitants of this area could have been using the atlatl since the nearby Aubrey, Clovis Site 41DN479, ~ 11,550 BP was occupied. In fact, some contend that the impact fractures found on Clovis and Paleoindian points could not have been produced without the atlatl (Bruce Bradley pers. comm.). The possibility that the atlatl technology was the weapon of choice for approximately 10,300 years makes it even more relevant that these people opted for a change to the bow and arrow. As Blitz (1988) points out, it was not an adaptive necessity; however, native groups from the Arctic to Texas adopted the technology in about a 400-500 year span. Indeed, as inferred through site densities, the Late Archaic in north central

Texas (Fig. 1.1) was a period of relative success compared to the Middle Archaic and there is little if any disagreement that these people were using the atlatl. Provided that the atlatl had been the primary weapon of choice and that populations were increasing in general, one could surmise that they were not suffering from reliance on the weapon. Why would they opt for the bow and arrow at the expense of such a time-tested weapon? There is no known evidence of mass capture of large game in north central Texas and as such this investigation will focus on the technologies that enabled them to procure the bulk of their protein and lipid resources: the atlatl (spear-thrower and dart) and the bow and arrow.

The overall strategy will: 1) Confirm that there was indeed a transition to the bow and arrow in north central Texas, 2) Elucidate through a chaine opertoire approach (operational sequences) to the lithic assemblage that there are fundamental differences in the reduction strategies, as well as patterns of maintenance and discard associated with each weapon system, 3) Demonstrate that there was a difference in the design construction of the projectile systems that suggests fundamental differences in the ontogeny and maintenance potentials, 4) Correlate lithic assemblages with the faunal record in an attempt to determine if groups using the bow and arrow were more successful than their spearthrower predecessors in terms of procuring high-ranked resources.

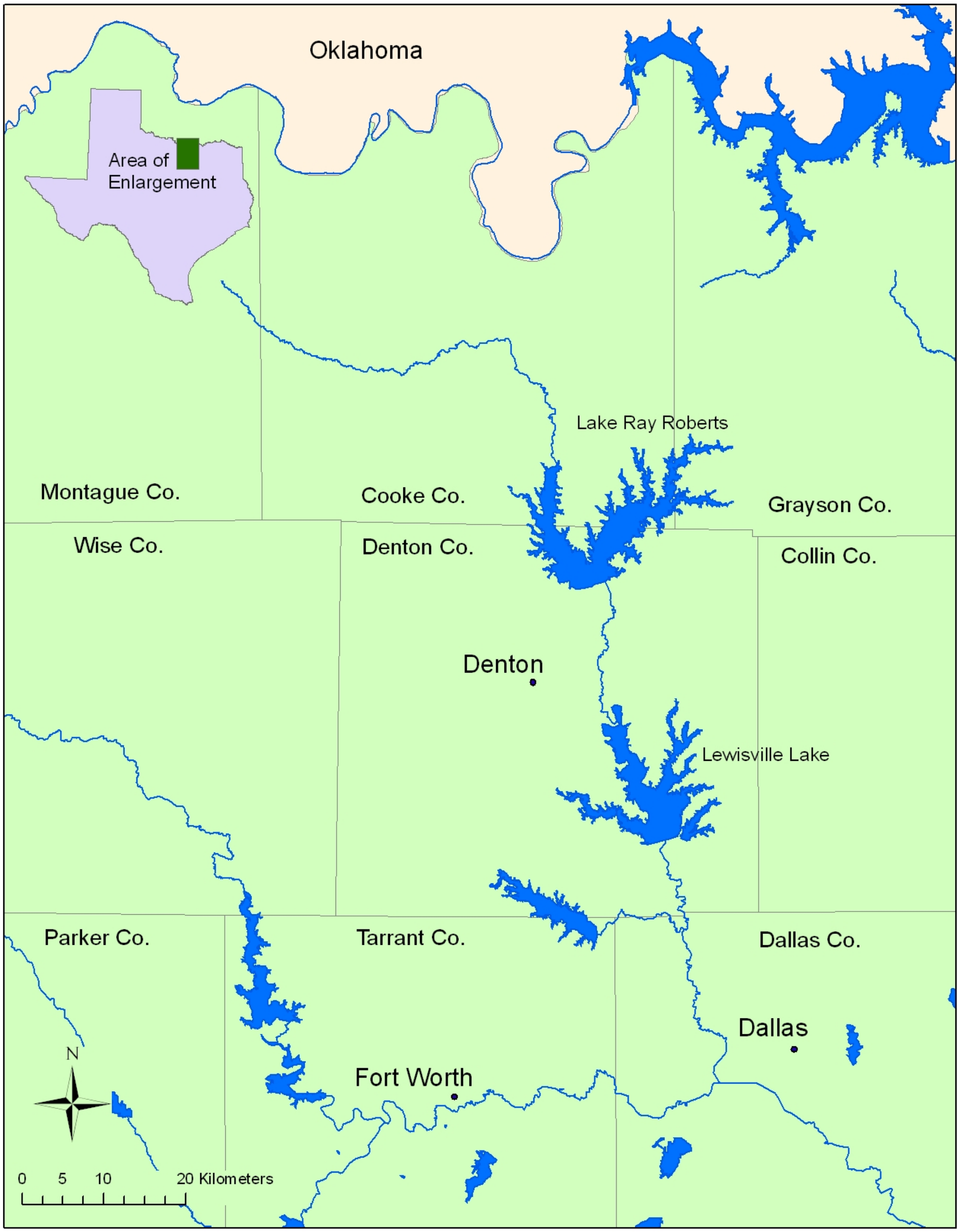


Figure 1.1**.** Map of north central Texas showing the Upper Trinity River with Lake Ray Roberts and Lake Lewisville.

The data used to conduct the study comes from eight sites at Lake Ray Roberts and four sites at Lake Lewisville on the Elm Fork Trinity River in the Upper Trinity River drainage in north-central Texas (Ferring and Yates 1997, 1998). These were excavated by the Center for Environmental Archaeology at the University of North Texas in the early 1990's and are appropriate because they contain Late Holocene components with requisite lithic and faunal assemblages. Some sites have components from a single time period and others have components from both the Late Archaic and Late Prehistoric periods. These are situated along the ecotone of the Grand Prairie, the Eastern Crosstimbers and the Blackland Prairie (Fig. 1.2).

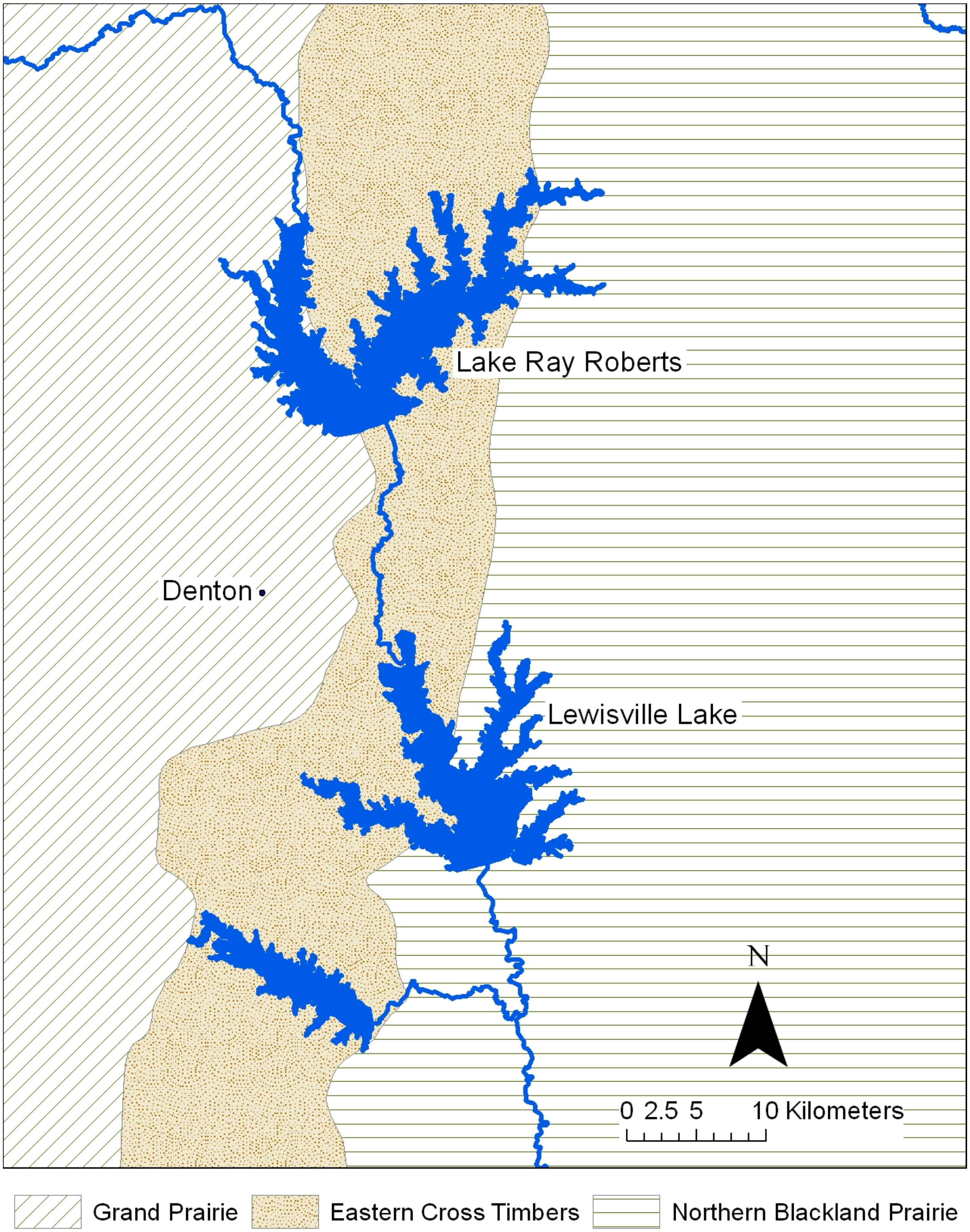


Figure 1.2. Physiographic map of the study area. Note the ecotonal position of the reservoirs at the boundaries between the Grand Prairie, Eastern Cross Timbers and the Blackland Prairie.

Research Design

This research is conducted through a Binfordian (1981) middle-range theoretical approach that is based on a synthesis of empirically demonstrated relationships in the archaeological record that are reflective of past human behaviors. It is done from a global perspective in that the background literature search takes examples from many different locales and sources to elucidate differences, similarities and commonalities in the archaeological record, the ethnographic record, historical accounts and experimental archaeology. In a general sense the scope will proceed with selected references from around the globe, to the Americas, to North America, to Texas, and finally to north central Texas. This comparative approach provides not only a sense of the overall variability but also gives some indication of the level of sophistication of the weapons that were used in north central Texas. And patterns evident from a broad geographic area provide support for inferences about a specific locale.

Unfortunately, there are scant remains of prehistoric spearthrowers, darts, bows or arrows in general and none are known from north central Texas. Thus other than the stone points, the remainder of the weapon systems has to be inferred. A comprehensive background on the weapons is crucial in this respect to provide some reference for theoretical warrant or inferences about the prehistoric efficiencies of the weapons: durability, design construction, methods of construction, hunting strategies, tracking ability and so on. Some of these parameters can be tested with replication, such as the durability of the weaponry or the physical/mechanical potentials in terms of velocity or distance. However, prehistoric efficiencies cannot be tested directly because there are no testable specimens, especially entire weapon systems. Arrows must be specifically tuned to bows as well as darts to spearthrowers. To truly test prehistoric efficiency in a rigorous sense the entire weapon system would be required along with people that possessed hunting and tracking abilities of a prehistoric level.

Binford (1981) offers the bear and footprint analogy to demonstrate that one can infer that a bear through available evidence produced a footprint but the cause cannot be known with certainty unless it was actually observed. Other than lithic and faunal remains, the perishable parts of the weapons as well as their methods of use and manufacture fall into the category of the past that has to be inferred. The lithic and faunal remains are analogous to the bear's footprint; humans are analogous to the bear, and presumably are the agent or cause responsible for the effects found on the stone tools, debitage, faunal remains and features. However, without being observed there is inherent uncertainty and the effects could be the result of site formation processes such as carnivore gnawing, trampling or geologic movement. Binford (1981: 32) cautions cogently not to make unwarranted assumptions about archaeological remains and explicates a sensible approach that utilizes middle-range research "where controlled information about causes and effects could be evaluated experientially rather than inferentially". This he contends will provide data to compare to the archaeological record, so that one will not assume for instance that all bone and attendant conditions are attributed to humans while not considering scavenging/carnivore damage. The actualistic research that I have conducted was initiated several years before the conception of this thesis project and consists of:

-35 years of bowhunting experience consisting of frogs, fish, aquatic turtles, rabbits, armadillo, feral hog, whitetail deer

-10 years experience in the construction of primitive style bows and arrows, spearthrowers and darts utilizing native materials

-Production of over 50 bows, the majority of which are selfbows while over 10 are sinew-reinforced

-Dispatch of 8 whitetail deer using primitive style bows and wooden arrows with *metal* tips

-Dispatch of 2 whitetail deer with primitive style bows, wooden arrows and *stone* tips

The bulk of the data generated by these actualistic endeavors are not specifically tailored to the thesis due to the fact that they were initiated earlier; however, the experiential research has been essential in assessing a variety of factors such as: manufacture time, durability, transportability and lethality. In short, they were invaluable in the physical and situational comparisons of the weapons, which are described in detail Table 1. To fully understand the technological transition, the weapons must be viewed from the system as a whole and not just the stone points. This aids in the identification of the traits that increased the bow and arrow's fitness in relation to the atlatl. Indeed, this global phenomenon indicates that there must have been some advantage to the adoption, and the faunal record from north central Texas will be tested to determine if it substantiates that claim. It is assumed that the adoption of the new and "advantageous" technology would have impacts on population size and security as it allowed them to procure food more efficiently.

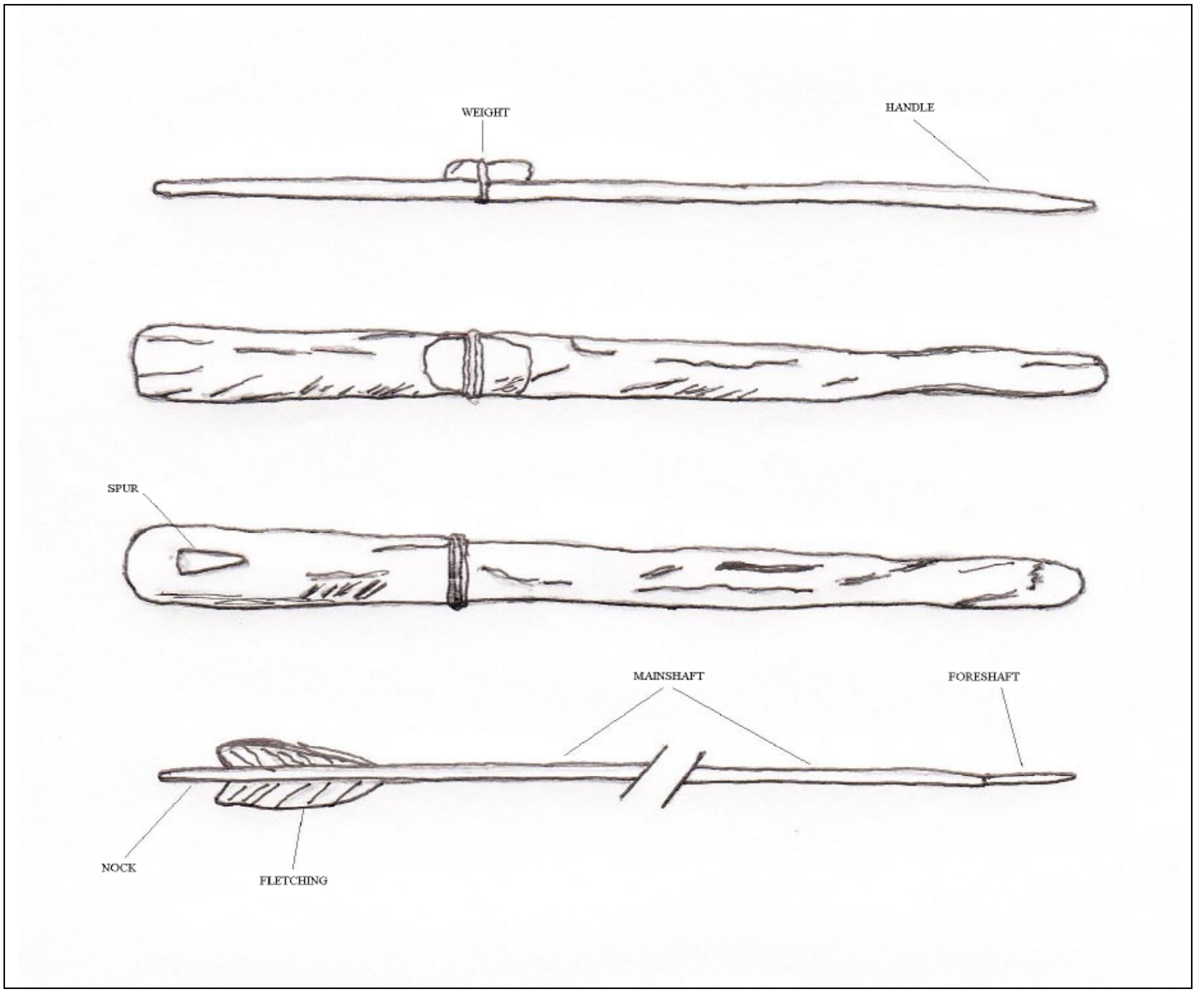
Technological Background

To undertake a comparison of the Late Holocene hunting technologies of the atlatl and bow and arrow a basic background is essential. This section will first provide a physical description of the weapons as well as an archaeological and ethnographic background on their production and use. Second, a comparison of the functional/performance abilities such as velocity, accuracy, effective range, rate of fire and portability will be provided. The stone projectile points that were employed with the atlatl and the bow and arrow will be discussed in a separate section due to their central focus in the thesis. They are the only substantial remains of the technologies in the archaeological record and as such will be used to identify/demonstrate the presence of the weapons in the assemblages.

Definition of The Atlatl

The atlatl has been referred to as “spearthrower,” “throwing stick,” “throwing board” and “sling contrivance for projectile weapons” (Cushing 1895; Dickson 1985; Knecht 1997; Whittaker 2005). The term “atlatl” derived from the Aztec language Nahua will be used in this study because that is what it is generally referred to in North America (Dickson 1985; Knecht 1997; Massey 1961). The weapon is a projectile-launching device that was used in hunting, fishing and warfare and consists of two basic parts, the spearthrower proper and the projectile (dart or spear) (Fig. 1.3). Together they are referred to as the atlatl. The spearthrower will be described first:

Figure 1.3 Atlatl (spearthrower) and dart (spear) schematic and nomenclature. (adapted from Raymond 1986).



(1) A stick or board usually less than 60 cm. in length equipped with a protrusion, sometimes referred to as a spur, at one end to engage a projectile shaft. This spur can be placed on the top of the stick (male type) or it can be inset into a cavity (female type). At the opposite end of the atlatl is the grip; these often possessed loops for the fingers fashioned into the wood itself or thongs of leather or some other material. The atlatl could be sized according to the physiology of the hunter or to the type of game being hunted. Cattelain (1997: 215) states that in Greenland, among other areas, atlatls used in conjunction with bird darts are generally much shorter (35-39 cm) than the atlatls used for hunting seals. Alternately he indicates that among the

Inuit of Unalit, the length of the atlatl used for seals or birds is equal to the length of the forearm measured from the elbow to the to the tip of the index finger. For hunting white whale, the atlatl would be the width of the index finger longer.

Often there would be a weight or bannerstone attached to the underside of the atlatl (Butler and Osborne 1959; Cushing 1895; Dickson 1985; Fenenga and Wheat 1940). These weights can be made from a variety of materials including gypsum, hematite, limestone, slate, quartzite, jasper and galena and range in size from 30 to 800 grams (Palter 1976: 503). Alternately, these can be carved onto the wood or antler of the atlatl shaft itself (Garrod 1955). Several of these have been found still attached to archaeological specimens (Cushing 1895; Fenenga and Wheat 1940; Mildner 1974). Thus, their association is clear but their function has been strongly debated. Some feel that they are actually a hindrance unless they are used with flexible atlatl (Palter 1976). Others contend that it aids in the balance of the atlatl and dart in the hand (Peets 1960) or that it stabilizes the weapon increasing accuracy (Butler 1975; Raymond 1986). Although there are some that feel that they were merely for decoration or ceremonial purposes (Hill 1948, 1949; McGregor 1965; Peets 1960).

(2) The projectile is a spearshaft or dart usually 50 to 70 percent longer than the actual spearthrower, ranging from 120 to 185 cm (Fig. 1.3) (Dickson 1985: 2). These could be fletched or unfletched (Cattelain 1997; Hughes 1998). The innovation of fletchings was an important step in the development of both the dart and arrow and as such bears full attention. This will be addressed fully in the dart and arrow fletching section.

The dart would often be compound with a removable foreshaft (Baker and Kidder 1937; Cattelain 1998; Fenenga and Wheat 1940; Hamilton 1982; Hare 2004; Lahren and Bonnichsen 1974); however, there are some examples of self-darts that were of single pieces of wood (Hare

2004). The size of the dart, as with the atlatl, would be dependent on the size of the user, the type of game being hunted, as well as availability of raw material and local cultural tradition (Cattelain 1997). Ethnographic accounts in the Arctic, Australia and other areas indicate that short, light darts would be used for aquatic birds and small animals such as seals, while longer, heavier darts would be used for large seals, whales and warfare.

Physics of the Atlatl

Most researchers agree that the atlatl's purpose is to increase the amount of propulsive force or initial velocity of the projectile (Cattelain 1997; Dickson 1985; Hughes 1998; Whittaker 2005); however, there is debate as to how this increase is achieved. Basically, the system works as a series of levers, and some feel that it is the lever action itself that is the most important in propulsion (Butler 1975). Others (Howard 1974; Krause 1905; Mason 1885) contend that the atlatl functions primarily by extending the time force is applied to the dart. Whittaker (2005: 13) has appropriately termed this "extended force." Essentially, the spur remains in contact with the cup on the proximal end of the dart as the arm moves forward and delivers the thrust to the projectile longer than with a hand thrown spear.

The advantage that it provided, compared to the long employed throwing or thrusting spear, was that it imparted substantially more velocity to the projectile. Primitive weapons such as the atlatl are considered low velocity (Beyer 1962: 115) and thus are subject to the force of gravity, which forces the projectile to travel in an arched trajectory. The increased velocity provided by the atlatl flattens trajectory and theoretically provides greater accuracy because the user does not have to adjust for the projectile's arch in flight (Hughes 1998; Klopsteg 1943).

Atlatl Ethnohistorical Accounts

The first mentions of the atlatl in history are from ethnographic accounts in the Americas. Early European ethnohistorians encountered the weapon in temperate climates such as Peru (Swanton 1938), Mexico (Defuentes 1963), Florida (Gilliland 1975), the Santa Barbara channel area of southern California (Heizer 1938), and Massey (1961) found reference to its usage in Baja California in the 17th century. Additionally, the DeSoto expedition was attacked by natives using the atlatl on the Gulf Coast near the mouth of the Mississippi River (Swanton 1938). In northern latitudes the weapon was found among the Aleuts and Eskimos (Murdoch 1892; Nelson 1899). Notably absent in these ethnographic accounts are examples from the interior of the North American continent as the bow and arrow had virtually replaced the atlatl in this area by the time of European contact (Driver 1961).

Abroad, ethnographers in Australia encountered the atlatl, which interestingly was the only continent that does not have evidence that the weapon was replaced by the bow and arrow. Charles Darwin (1909: 457) accounts its usage among the Aborigines as he traveled on the Beagle in 1836 near Bathhurst, and Davidson (1936) classified atlatl types and their distribution on the continent.

In late 19th century North America, atlatl technology began to receive scholarly attention. In the Arctic, Mason (1885) described Eskimo "throwing sticks," provided a distribution of different types and noted that the atlatl was more appropriate for usage in a kayak than the bow and arrow due the latter's susceptibility to moisture. And in Mesoamerica, Zelia Nuttal (1891) described the "atlatl" after reviewing Aztec codices and Spanish historical records. Interestingly, Mason and Nuttal are credited for the predominance of the usage of the term atlatl in America (Whittaker 2005). Around the same time, archaeological pioneer Frank Cushing (1895) constructed various types of atlatls and other similar contrivances, which he attempted to place into an evolutionary scheme leading to the bow and arrow. Though there does not seem to be any evidence that the bow evolved out of the atlatl technology, this experimentation gave Cushing (1896) enough of an understanding that he was able to identify some of the first excavated atlatl fragments in the Florida Keys. Similarly, these early ethnographic accounts illuminated the widespread usage of the weapon and in turn archaeologists began to attempt to identify it in the archaeological record.

Atlatl Archaeology

It is now widely accepted that the thrusting and or throwing spear preceded the atlatl and that this technology was eventually replaced by the bow and arrow in the Old World as well as the New World (Cattelain 1997; Hughes 1998; Knecht 1997). The exact timing of the chronology is difficult to ascertain due to the perishable nature of the weapons other than the stone points. Fortunately the earliest atlatls in Europe were compound in construction and some of the distal extremities made from antler, bone or ivory (Cattelain 1997) have survived to indicate the weapons presence in the archaeological record. The earliest known specimen is an antler spur from the Upper Solutrean site Combe Saunière radiocarbon dated to 17,470 ± 249 bp (Lyon 3329) (Knecht 1994: 11). Cattelain (1997: 214) indicates that the atlatl was used extensively from the Upper Solutrean (± 17,500 bp) until the Upper Magdalenian (± 12,500 bp) in southwest France, Switzerland, eastern Germany and Spain. Some feel that the technology is considerably older and was present as far back as the Middle Paleolithic (Cressman and Krieger 1940; Knecht 1994; Krause 1905; Massey 1961).

In the New World, several researchers contend that the atlatl has been used since the Paleoindian period (Ahler and Geib 2000; Christenson 1986; Frison 1989, 1993) and Hughes (1998) asserts that it was employed by 9200 bp at Mummy Cave in northwestern Wyoming. Bradley (1999 pers comm.) asserts that the impact fractures present on Clovis points could not have been created without the speed generated by the atlatl and thus were not produced by the thrusting spear (cf. Hutchings 1997 from Whittaker 2005). Additionally, some of the bone and antler artifacts from this period are thought to be remnants of foreshafts used with the technology. Similar to the aforementioned Solutrean atlatl spur there is a possible spur dated to 10,000 bp in New Mexico (Judge 1973); however, the earliest definite archaeological specimen of an atlatl is from Fort Rock Cave in Oregon (Cressman 1977: 105) dated to the Early Archaic period (8,500-6,000 bp). Additionally, there is a dart shaft fragment from the Yukon that is dated to 8360 ± 60 (Hare 2004). There are many more partial and whole archaeological examples found in dry caves and rockshelters from the Great Basin and the Southwest (Baker and Kidder 1937; Cressman and Krieger 1940; Fenenga and Wheat 1940; Mildner 1974) and in eastern North America there are numerous Archaic period specimens from grave lot contexts (Dickson 1985; Tuck 1970; Webb 1946; Webb and Haag 1939). Whittaker (2005) indicates that there are more than 60 complete and partial specimens, not counting spurs and weights, referenced from the Americas. Unfortunately many of these, especially the specimens from the southwest, were found out of context or were not dated (Baker and Kidder 1937; Cressman and Krieger 1940; Cushing 1896; Fenenga and Wheat 1940) and are essentially useless for establishing any type of chronological context.

Atlatl Technology of the Study Area

In the immediate study area there are no known archaeological specimens of spearthrowers or darts; however, there are two from the region. The first specimen is from a cave on the Cimarron River, near Boise City, on the High Plains of northwest Oklahoma (Baker and Kidder 1937). It was recovered in 1928 during “limited digging” along with a slotted foreshaft, ears and cobs of maize, a twined woven bag, yucca sandals, two skeletons and a child’s mummy. The foreshaft indicates that the darts were compound. The atlatl specimen is fragmentary and total length cannot be determined although it can be described as a female type as the spur is inset and does not protrude above the shaft. This is in contrast to the specimens found in the vicinity of El Paso, Texas (Baker and Kidder 1937: 52); however, it is quite similar to the one that will be discussed next.

A specimen was recovered in 1938 during “superficial excavations” in the Trans Pecos region at the Baylor Rockshelter, Culberson County, Texas (Fenenga and Wheat 1940: 221). It was in association with yucca sandals, cordage, undecorated pottery sherds, a drill, a projectile point and compound dart fragments. Unfortunately the point was not described. This complete specimen, like the Cimarron atlatl is a female type; however, it still has a weight attached to the underside. Both (Baker and Kidder 1937) and (Fenenga and Wheat 1940) hypothesize that their specimens had leather fingerloops attached on the proximal end. Several typologically similar specimens to these have been found in the Southwest (Fenenga and Wheat 1940: 222). Though it cannot be substantiated, it could be expected that the atlatls employed during the Late Archaic period (3500-1250 BP) in the study area would have been much the same. Which is a female atlatl, minimally decorated or artistically conservative, that also may have a weight attached.

Definition of the Bow and Arrow

The term atlatl implies both the spearthrower and the dart and as such those were described together, while the bow and arrow will be treated separately in this section. An emphasis will be placed on why a particular bow type was used because this has a bearing on efficiency, style of hunting and durability.

As with the atlatl, the bow is a projectile-launching weapon that was used for hunting, fishing and warfare. The bow is basically a spring consisting of two flexible limbs that are held under tension with a string. When the bow is drawn back, potential energy is stored in the limbs and upon release the energy is transferred to the arrow, which is cast forward (Hamilton 1982: 1; Cattelain 1997: 219).

There is a large amount of variability in dimensions, types and efficiencies of prehistoric bows; however, they can be placed in three broad categories, which are the selfbow, the reinforced bow and the composite bow (Bergman and McEwen 1997). The bows in each of these categories can exhibit a variety of different profiles and thus these categories reflect the materials of construction and not the side view profile of the bow itself. Profiles include: straight bows, reflexed bows, double-curved bows (Cattelain 1997; Hamilton 1982; Hamm 1991), and asymmetric bows (La Fleche 1926). The selfbow will be described first and at length and although there is some evidence that the reinforced bow was present in the Southwest at approximately 800 BP (LeBlanc 1997), there does not seem to be any evidence that it or the composite bow was employed in prehistory in the north-central Texas study area and therefore they will only be discussed briefly.

Selfbow

The most widely distributed and most basic bow is the *selfbow*, which is usually constructed from a single stave or piece of wood (Fig 1.4). However, in Asia, other materials such as water buffalo horn (*Bubalus bubalis*) were substituted as in the case of the Javanese self-horn bows due to a lack of suitable wood (Bergman and McEwen 1997). There is a great range in the potential abilities of selfbows because this category includes mere bent sticks with a string attached that many have made as a child, to what some, especially Europeans, would call the pinnacle of archery, the English longbow. Draw weights vary widely ranging from 35 to 100 lbs (Cattelain 1997; Hamilton 1982; Pope 1923). The heaviest bows in the 80 to 100 lb range are primarily associated with European weapons of warfare while North American bows generally range from 35 to 55 lbs (Hamilton 1982; Hamm 1991; Pope 1923). The selfbow exhibits a great degree of morphometric variation with some bows as short as 100 cm. and others such as the aforementioned longbow being as long as 200 cm. (Cattelain 1997). Cross sections of selfbows range from a flat, rectangular style found in North America and Europe, to an elliptical style in some parts of North America, to a round cross section found primarily in Africa, as well as a U-shaped cross section in the case of the English longbow (Hamilton 1982; Cattelain 1997). In North America the most common side view profile of the selfbow is the simple D-bow, while some are double curved and a few are recurved at the tips (Fig. 1.5). Interestingly, Hamilton (1982: 6) indicates that the double curved bow (Fig. 1.5 b) is only found in North America while the while in South America the only type of side view profile is the D-bow.

Figure 1.4 Selfbow schematic and terminology used by European bowyers for at least five centuries (adapted from Bergman and McEwen 1997).

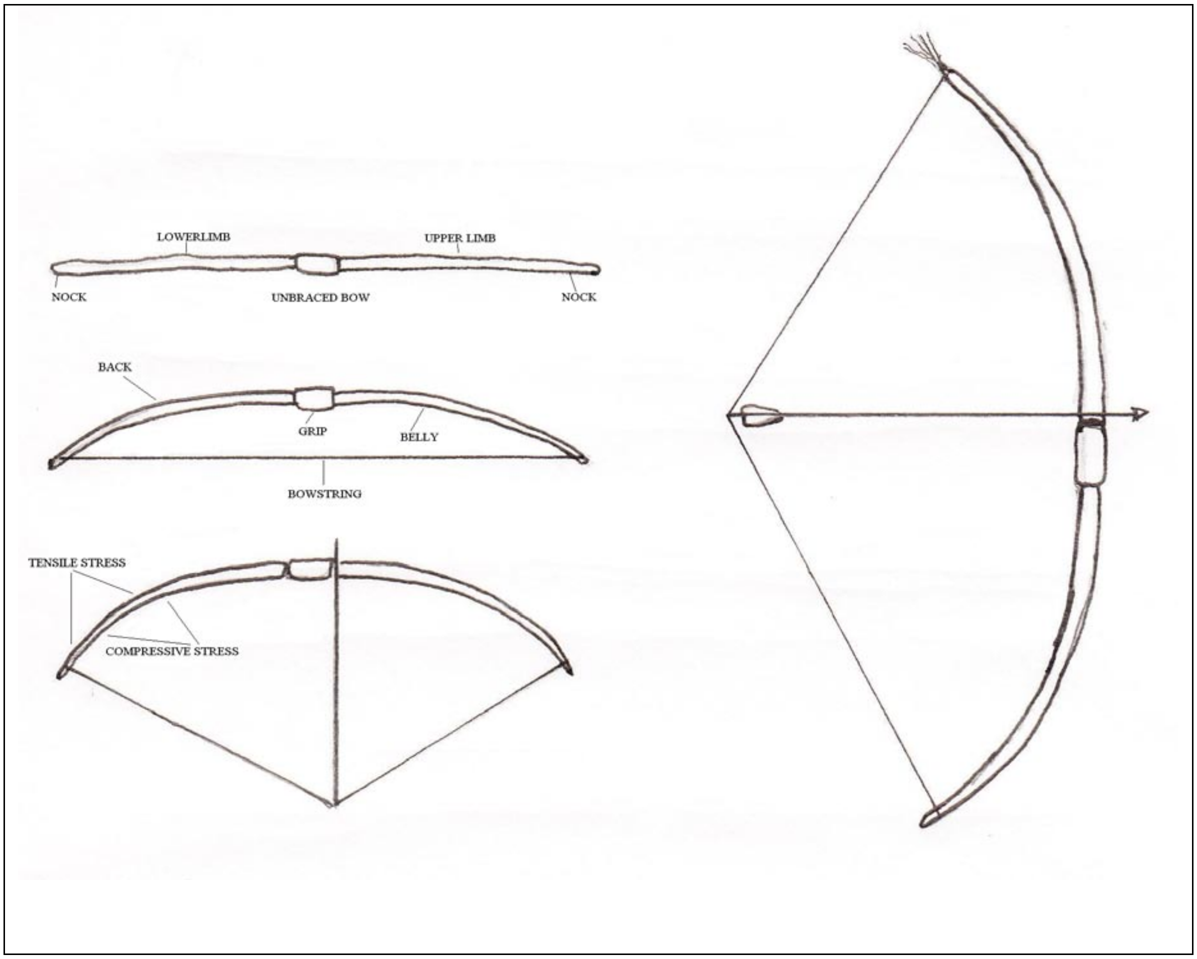
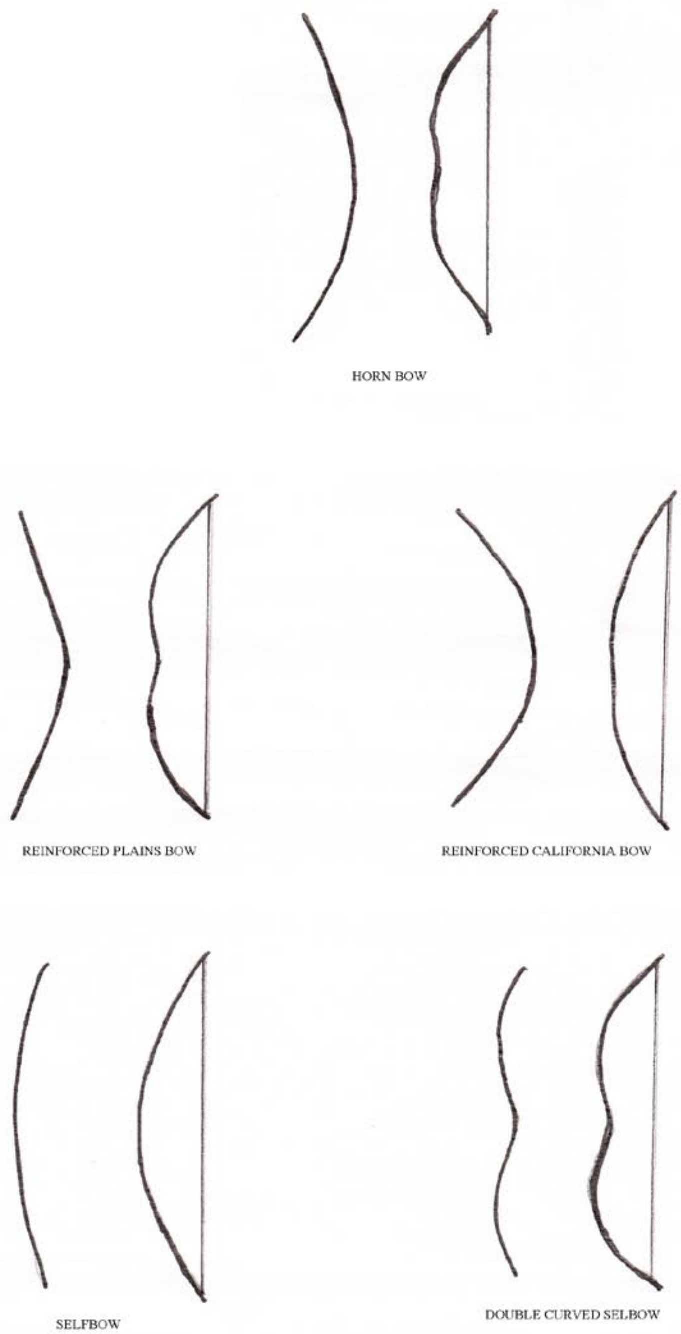


Figure 1.5 Side view profiles of various bows, relaxed and braced. Top row, Horn Bow Middle row, reinforced: Reinforced Plains Bow and California Bow. Bottom row, self-bows: D-bow and Double-Curved. (adapted from Hamilton1982).



Reinforced Bow

The *reinforced bow* is a wooden selfbow that has sinew applied with hide or fish glue to the back of the bow (the part that faces away from the archer and is under tension) (Fig. 1.4) (Bergman and McEwen 1997; Hamm 1992). The sinew is usually from the Achilles tendon or dorsal fascia area of animals such as deer, elk, moose, caribou or bison. This is usually applied in a sheet from a one to three layers thick or it can be corded and bound as in the case of Eskimo bows. Sinew is extremely elastic and exceeds the elasticity of wood by about five times before breaking. Essentially, sinew stretches about 20% before failure, while wood stretches less than 2% (Bergman and McEwen 1997:145). This being applied to the back reduces the chance of breakage because it increases tensile strength. Additionally, it allows a bow to be drastically shortened without a reduction in draw length. This provides a lower draw length to bow length ratio that results in a flatter trajectory and a longer cast for the arrow. Overall the sinew-reinforced bow in comparison to the selfbow increases efficiency and provides a weapon that is more suited to use on horseback or in confined spaces due to its reduction in length. The composite bow took this concept to another level.

Composite Bow

The *composite bow* requires a considerable amount of skill to produce and is mechanically a "tour de force" (Bergman and McEwen 1997: 145). Hamilton (1982: 9) characterizes the Asiatic composite as the "ultimate in bow design" and states that it was the result of a long period of experimentation in a quest to find a weapon that was superior in cast to the reinforced bow.

There are two basic types, the Asiatic, and the North American. The Asiatic bow is the older of the two and utilizes a thin wooden core and has a sinew glued to the back allowing for incredible elasticity, while the belly is made from horn (usually water buffalo), which has 3.5 times more compressive strength than wood (Bergman and McEwen 1997: 145). For instance, Grayson (1993: 116) indicates that water buffalo horn can withstand about 1800 kg or two tons of longitudinal compression before failure.

The North American composite bow by contrast usually does not have a wood core and thus simply has a sinew back and a horn or antler belly. The compression resistant material for the belly can come from Mountain sheep (*Ovis canadensis* or related species) horn, elk (*Cervus canadensis*) or caribou (*Rangifer tarandus*) antler, bison horn (*Bison bison*), or in the case of some bows from Greenland, whale baleen (Grayson 1993). Some have postulated that the ribs of bison were used for the belly at times, but this has not been substantiated (Bergman and McEwen 1997).

There is some debate over the reasons for the development of the composite and reinforced bows and the impetus was probably different according to time period and geographic location. Some posit that there was an ecological impetus and point to the fact that the technologies were not generally present in areas that have suitable wood to construct quality bows (Balfour 1890); however, archaeological data indicate that the composite bow first appeared in locations such as Egypt that had ample access to hardwoods that were suitable for selfbow manufacture (Bergman and McEwen 1997). Others contend that they were an attempt to produce a mechanically superior weapon that had greater cast (Hamilton 1982). And yet others have surmised that it was developed in response to equid transport in the 3rd millennium B.C. in Asia and similarly in the New World as the horse was introduced by the Europeans

(Bergman and McEwen 1997; Cattelain 1997). Shorter bows are certainly more maneuverable on horseback.

However, an equid adaptation is not the only reason for a short bow. For instance, among many Historic period Native American groups in California such as the Yana and Hupa, the horse never made a serious impact on hunting or warfare strategies; however, they manufactured and used short sinew-reinforced bows (Wilke 1988). This is in response to two factors, raw material limitations and hunting strategy. The primary wood used for the construction of bows was Juniper (*Juniperus osteosperma* and related species) (cf. Ishi from Pope 1918) that generally only yields short bow staves. Thus, the bow must be short. Similarly, Bergman and McEwen (1997: 158) note that the lengths of North American composite bows are limited by the length of elk/caribou antler or mountain sheep horn from which they are constructed.

Hunting strategy also factored into the type of bow that would be used. Bergman and McEwen (1997) indicate that even though there was suitable wood such as yew (*Taxus brevifolia*) for making longer bows, the Native Americans west of the Sierras selected juniper and related species such as incense cedar (Ishi used both; Pope 1918) because they are more suitable to making short sinew reinforced bows (145 cm. and under). Their primary method of hunting was by trailside blinds in dense forests, which would render a longbow difficult to use. Pope (1918) notes that Ishi preferred to shoot his bow from a kneeling position and his favorite hunting method for large game was to wait in the underbrush, in ambush along a game trail. This demonstrates the necessity for a short bow because just as a long bow will be interfered with by a horse's neck it will also come into contact with the ground if the archer is kneeling.

The Arrow

The projectile used with the bow is an arrow, and as with the bow, there is a great deal of morphological variability viewed from a global perspective. The type of arrow used is a result of the weight of the bow, available raw materials and the type of game hunted. Primitive weapons operate by the transfer of human energy to a projectile. In the case of the bow, potential energy is stored in the limbs as the archer pulls the string to the anchor point. Upon release, the human action is converted to motion that propels the arrow to its target (Hughes 1998). The transfer of this energy is not total as some is dissipated in the shaft, creating vibration and lateral oscillation that continues through the early phase of flight (Klopsteg 1943; Perkins 1992). Basically, if the spine or stiffness of the projectile is insufficient or the mass is not in accordance with mass of the propulsive device, buckling or deflection will occur. In a general sense, the oscillation of the arrow must be "tuned" to the bow by varying the stiffness of the shaft or the weight of the bow. An arrow shaft that is too limber will not oscillate rapidly enough, resulting in the arrow striking the handle of the bow. If the shaft is too stiff it will oscillate too rapidly, propelling the arrow to the left of the target (Klopsteg 1943). The spine of the shaft can be influenced by several factors: reducing the diameter, shortening the shaft (Klopsteg 1943; Perkins 1992), varying the weight of the tip (Hughes 1998), raw material type (Hamm 1991), or the presence or absence and type of fletchings (Hughes 1998). The more closely the bow and arrow are matched, the easier it will be to achieve maximum efficiency and accuracy.

Raw materials and lengths of arrows vary according to geographic locale. As a general rule, there are few prehistoric specimens, especially ones from archaeological deposits of integrity. Thus, some historic specimens will be included to this discussion. These will be briefly reviewed, first in the Old World, then in the New World and finally with a focus in the region of the study area.

Several complete pine arrow shafts have been recovered from Stellmoor, Germany that date to the Upper Paleolithic. The lengths are often greater than 73 cm. (29”) without points or foreshafts. Some of the shafts are sharpened (simple self arrows), while others still have fragments of points still in the haft (Cattelain 1997: 222). In Africa, there is a paucity of data concerning prehistoric arrows. Arrows used by the Dahomey are short, from 64-70 cm. (24-28”) and weigh between 15 and 30 g (Cattelain 1997). This in contrast to Hadza arrows, which are relatively, long 120 cm (47”) and break quite easily. As they are broken, they are shortened and refitted with a new point. This process will continue until the length of the shaft is exhausted (Cattelain 1997:222).

In Arctic regions of the New World, Pope (1923: 338) indicates that Inuit wooden arrows associated with a bow of 80 lb draw weight, had lengths of 62 to 97 cm with an average of 74 cm (29”). North of the Bering Strait, Mason (1893: pl. LII-LX) reviewed some shorter arrows that had lengths ranging from 43-56 cm. Interestingly, Cattelain (1997: 224) studied a small sample of 16 stone and bone points from these arrows and found they are *morphologically identical* to spear points used with a spearthrower. The stone points had lengths ranging from 5 to 11 mm (average: 7mm), while the lengths of the bone points range from 7 to 24.5 cm (average: 16.6). The fact that the points used for the atlatl and the bow and arrow were identical illustrates that at least in some cases, there is an overlap in the points that can be used with the two weapon systems. This issue will be addressed in full in the section on the identification of the weapon systems/stone points.

There are two basic divisions of arrows predicated by raw material type in North America (Hamilton 1982; Allely and Hamm 1999, 2002; also see Hamm 1991 for a list of preferred woods). In forested areas or prairies, young hardwood shoots or split and reduced timber were used and in more arid climes cane or reed was popular. More specifically, in the Plains shafts were 50-66 cm long (20-26”) and usually constructed from roughleaf dogwood (*Cornus drummondii*) in the south, while in the north red osier dogwood (*Cornus sericea*) and wild rose predominated. In the southwest shafts were generally 66-86 cm (26-34”) in the length and fashioned from phragmites reed (*Phragmites austrailis*) as well as hardwood shoots (Allely and Hamm 2002). It can be assumed that the majority of the cane or reed arrows were compound in construction (Birmingham et al. 2005; Hamilton 1982; Hamm 2002; Fenenga and Riddell 1949) and utilized a foreshaft. This is because the wall of the shaft is simply too fragile to haft a point to directly, and a self-arrow (made from one material) constructed from cane or reed only would likely be too light. In the northeast, shafts were 64-90 cm. in length (25-35”) and were usually constructed from timber such as ash or hickory (Allely and Hamm 1999). This was often split and reduced or alternately hardwood shafts were used. Shafts were much the same in timbered areas of the southeast although reed or cane was sometimes used (Swanton 1938). As with bows, it is obvious that there is marked diversity in lengths and raw materials employed in arrow construction in the U.S. There is much more differentiation in arrow types and raw materials used globally that could be reviewed; however, this demonstrates that a variety of materials were appropriate. Any of these materials, if constructed appropriately, can work as an arrow.

Dart and Arrow Fletchings

As with sinew used to haft points and bind fletchings, the fletchings are one of the first items to degrade or decompose and thus are even less common in archaeological deposits. They are usually made from the feathers of large birds such as turkey, hawks, eagles, vultures, or geese and range in length from 5-23cm (2-9”). There are two basic types of fletchings: tangential and radial (Hamilton 1982). The tangential method is older and more primitive and consists of lashing down a complete wing or tail feather on opposing sides of the shaft. It was used on the dart but not the arrow. The radial method, used with both technologies, is more common and usually consists of three feathers that have been stripped from the quill. These are placed separately and perpendicularly around the shaft at 120˚ intervals. The former method does not provide as efficient flight as the latter method because it is bulkier and not as aerodynamic. There is basically too much air resistance. Conversely, the radial method if done correctly can be highly aerodynamic and efficient. Essentially, the fletchings act as a rudder and stabilize the projectile as it oscillates after being thrust forward.

It is assumed that most darts and arrows used prehistorically in North America possessed fletchings; however, they are not essential for proper flight. There are a number of ethnographic examples of groups that employ unfletched darts and arrows. These shafts are generally longer and heavier, which compensates for a lack of fletchings. Hughes (1998) posits that the heavier shafts are inherently more stable and less affected by drag, and that early dart shafts at Mummy Cave were unfletched. She contends that this is evidenced by heavier dart points prior to 7500 BP and provides ethnographic and experimental data that illustrate that fletched darts are lighter and smaller than unfletched darts although there is some overlap. Similarly, Evans’ (1957) experiments indicate that a heavier point when using unfletched arrows significantly aided accuracy. A heavy point or longer shaft is required on an unfletched shaft because the increased forward weight is necessary to provide balance. The addition of fletchings creates more surface area at the rear of the projectile, increasing rear drag, which creates a spin that keeps it tangent to the flight path (Higgins 1933; Klopsteg 1943). This allows for a smaller shaft and a smaller point as well. Thus as Hughes (1998) asserts, a diachronic change in mean point weight could indicate that there was a shift from unfletched to fletched shafts be they dart or arrow.

Physics of the Bow and Arrow

In the evolution of primitive weaponry there was selective pressure towards weapon systems of greater velocity thereby increasing accuracy. Just as the atlatl increased the velocity of the projectile compared to the thrusting spear or throwing spear, the bow and arrow did so in a similar manner compared to the spearthrower and dart. The bow is simply a more efficient method of transferring energy to the projectile, thus increasing velocity. Theoretically, the flatter the trajectory of the projectile, the easier it should be for the hunter to achieve an accurate shot because they do not have to adjust their point of aim due to the arch of the projectile (Hughes 1998; Klopsteg 1943). Hughes (1998: 352) indicates in a study of ethnographic specimens and replicas that while the atlatl offered only modest gains in terms of velocity (17.8 to 23.6 m/sec) compared to the throwing spear, the mean velocity of the bow and arrow is approximately twice that of the atlatl (46.9 to 23.6 m/sec). While increased velocity is the key variable in terms of accuracy it is not the only variable influencing penetration.

Unlike high velocity weapons such as bullets and missiles, low velocity projectiles kill by slicing and subsequent blood loss (Beyer 1962; Friis-Hansen 1990; Pope 1962). Thus depth of penetration is of utmost importance, and the deeper a low velocity projectile penetrates the more blood loss it can potentially create. Friis-Hansen (1990) states that a minimum of 20 cm. (8”) of penetration is required to inflict significant internal hemorrhaging in large ungulates; 15 cm. (6”) of penetration is a minimum for humans (Jauhari and Bandyopadhyay 1976). Hughes’ (1998: 352) research indicates that deeper penetration is basically the result of increased kinetic energy. Which can be expressed as the energy of a body with mass *m* moving at a velocity *v* is one half the product of the mass of the body and the square of its velocity, i.e., $KE = 1/2mv^2$. She demonstrates that the mean KE for hand thrown spears is substantially more than the dart, from 75.4 compared to 32.5. However, there is little difference between the dart and arrow (32.5 to 29.9). This implies that the increased velocity of the projectile was more important to the prehistoric users than increased kinetic energy. Globally there was a trend towards lighter projectiles with higher velocity (Hughes 1998). Hughes (1998) demonstrates this at Mummy Cave, although she contends that the thrusting spear was held over for specific purposes such as dispatching wounded animals at close range.

Bow and Arrow Ethnohistorical Accounts

In general people are not as informed of the atlatl, its geographic distribution, and its role in history (e.g. Aztec or Native American encounters with Europeans) as they are of the bow and arrow. Thus the section on Atlatl Ethnohistorical Accounts was provided to illustrate the technologies global employment and the fact that its use persisted well into the Historic period in certain areas. However, there is no question as to the bow and arrows ubiquity and role in history. Essentially the accounts of the bow and arrow since the time of written history are too numerous to fully review in this work (for an in-depth review of the Old World see Clark 1963;

Rausing 1967; in North America see Hamilton 1982). This section will briefly discuss the weapon through the period of written history, starting with the earliest civilizations.

The bow and arrow's presence is well demonstrated in the Old World and New World; it was found in all areas other than Australia and perhaps parts of Polynesia (Cattelain 1997). It was employed by the first civilizations in Sumeria and Egypt respectively (Rausing 1967). Unfortunately there is little if any documentation of the bow and arrow's role in subsistence during the earliest time of written history; however, there are some depictions such as The Hunter's Palette (Late Predynastic) (Rausing 1967) that indicate that it was used for hunting. The vast majority of accounts and depictions of the weapon are from military contexts, as evidenced by numerous stelae including Naram-Sin, King of Akkad (2250 B.C.). Judging from the side view profile, Rausing (1967) states that the bows in the previous figures appear to be of the more sophisticated composite type, indicating that the simpler more primitive selfbow had been replaced by the time of cuneiform and Sumerian clay tablets.

The short, highly efficient and powerfully-reflexed composite bow discussed in the Definition of the Bow continued to play an important role in Indo-European history, in particular on the Steppes of southern Russia, with a series of nomadic equestrian groups taking control (Hamm 1993; 1; Latham and Peterson 1970). A case in point is a battle in 512 B.C. between Persian foot soldiers numbering around 700,000, led by Darius the 1st and a nomadic tribe of Steppe herdsman, the Scythians, numbering around 10,000. In this encounter the greatly outnumbered mounted warriors defeated the powerful Persians who could not get close enough to inflict damage. In turn, other Indo-European and Turko-Mongol nomadic horse-archers would take control, including groups such as the Parthians, the Huns, the Bulgars, the Mongols and the Turks. This could be viewed as an early arms race, as the group that had the most efficient bow could launch projectiles from a greater distance, which afforded greater safety. Interestingly, one gentleman in 1913, shooting a two hundred year old Turkish composite bow of 80 lbs. shot 972 yds. (888.48 m) (Rausing 1967: 3). The Turkish bow held flight distance records until the advent of fiberglass in the 20th century.

The situation was quite similar later in time in Europe, as the English longbow was possibly the deciding factor at legendary battles such as Agincourt, Poitiers and Hastings. More specifically, at Crecy in 1346 A.D. around 5,000 English longbowmen played a pivotal role in defeating 100,000 French crossbowmen (Massey 1993). The bow had greater striking power, longer range, and more rapid speed of fire than the crossbow. Perhaps most importantly, as a crossbowman primed their weapon by cranking the handle, the archers continued to fire, as a skilled English archer could fire ten arrows a minute (Spielvogel 1997). This is the exact situation the early Europeans in North America encountered as they attempted to reload their harquebus while the Natives continued to fire at several times the rate of the colonists.

In the New World, the earliest interactions with the Natives are rich with eyewitness accounts of the weapon in the 16th century from Europeans such as John Smith (Willoughby 1907) in Virginia, Hernando De Soto (Elvas 1907) in the Southeast and Cabeza de Vaca (1907) and Diego Perez de Luxan (Hammond and Rey 1929) in the Southwest. Unlike the earliest evidence of the bow in the Old World during the Historic period, the bow and arrow in North American accounts was often associated with hunting as well as warfare. There are numerous accounts of Native hunting techniques and prowess. John Smith witnessed deer drives utilizing fire and noise to push the animals into hunters waiting in ambush. Alternately, the animals were driven into rivers where hunters in canoes would dispatch them (Willoughby 1907). There is some continuity in methods diachronically as well as geographically evidenced by some accounts. Smith in the early 1600’s observed individual hunters in Virginia disguising themselves by wearing a deerskin with a stuffed head, allowing them to stalk up to their prey without detection. George Catlin (1973) witnessed this same stalking technique on the Plains in the 1830’s, Ishi employed it on the Northwest coast in the early 1900’s (Pope 1918), and the Havasupai still used it in 1918 to hunt antelope, deer, and mountain sheep in the Grand Canyon in north central Arizona (Spier 1928). And finally, within the region the Caddo employed the technique in the 1870’s (Swanton 1942).

The early Europeans description of Native bows is conditioned by their familiarity and conception of Old World bows. They knew of two basic types, the fabled English longbow, and the Asiatic composite hornbow, which they knew from Turkish conquests. The longbow forms a “D” in profile, while the hornbow forms what is sometimes refered to as a “Cupid’s bow” in profile (Fig. 1.5). Thus in their descriptions of Native American bows they described them in those terms. They viewed wooden selfbows over 5” to be of the English longbow type (e.g. John Smith ca. 1607-1609), while shorter reflexed or recurved bows (Fig. 1.5) such as those encountered in Texas by Cabeza de Vaca 1542 (1907) and by Luxan in 1582 (Hammond and Rey 1929) in New Mexico were described as Turkish. East of the Mississippi, Europeans encountered Natives using only the selfbow, while to the west they found selfbows, reinforced bows and “Turkish” composite bows in use (Hamilton 1982).

Old World Archaeological Evidence

Clark (1963: 61) postulates that the bow was in use in the Late Solutrean; however, the earliest secure archaeological evidence was discovered in a peat bog in Stellmoor, in present day Germany, at an Ahrensburgian site dated to the final Paleolithic (± 11,000 BP) (Rausing 1967).

The remains consisted of fragments of straight selfbows and 100 arrows that were made of pine heartwood (*Pinus silvestris*). Given that pine is generally considered to be an inferior wood for bow construction, some contend that these bows could have been reinforced with sinew or some other material (Beckoff 1968; Cattelain 1997); however, there is no evidence to support this claim.

Several bows have been recovered from bogs in Holmegaard, Denmark and the surrounding region that date to the end of the Boreal (± 8,000 BP) (Cattelain 1997; Clarke 1963; Comstock 1993; Rausing 1967). This style of bow consisted of long, straight, wide-limbed selfbows that were made for about 4000 years (Comstock 1993: 87). The earliest examples are made from elm, while some of the later examples found in Germany are made from yew.

The difference between the Stellmoor bow and the Holmegaard bows are the orientation of the bows in reference to the growth rings of the wood. Most bows since the Bronze Age in Europe and modern bows in particular have been oriented so that the back of the bow is made from the outer bark-side of the tree (Comstock 1993). Essentially, the back of the bow follows a single growth ring of the tree for its entire length. This is the most efficient design because the parts of the tree that can withstand the greatest tensile forces are used for the back of the bow, which is under tension (Fig. 1.4). The Stellmoor bow was constructed perpendicular to this orientation so that the edges of the growth rings are visible on the back of the bow (Fig. 1.6) (Rausing 1967). In contrast the Holmegaard bows were bent *backward,* in that the interior of the tree was used as the back of the bow (Comstock 1993: 91). This is the opposite orientation of the aforementioned single-ring method. Obviously bows can be constructed in such a manner; however, they must be *overbowed*. Which entails that the bow is longer and wider than usual to withstand the additional stress of having growth rings exposed on the back of the bow. The additional size compensates for the fact that the bow was not constructed to optimally utilize the mechanical properties of the wood and allows the bow to be made without backing. It is possible that this was a limiting factor on the strength of bows that could be produced until the advent of the following a single growth-ring method in the Bronze Age. The reason for the use of the edge-ringed method on the Stellmoor and Holmegaard bows is not clear; however, the vast majority of bows produced since then has followed a single growth ring (Comstock1993: 90).

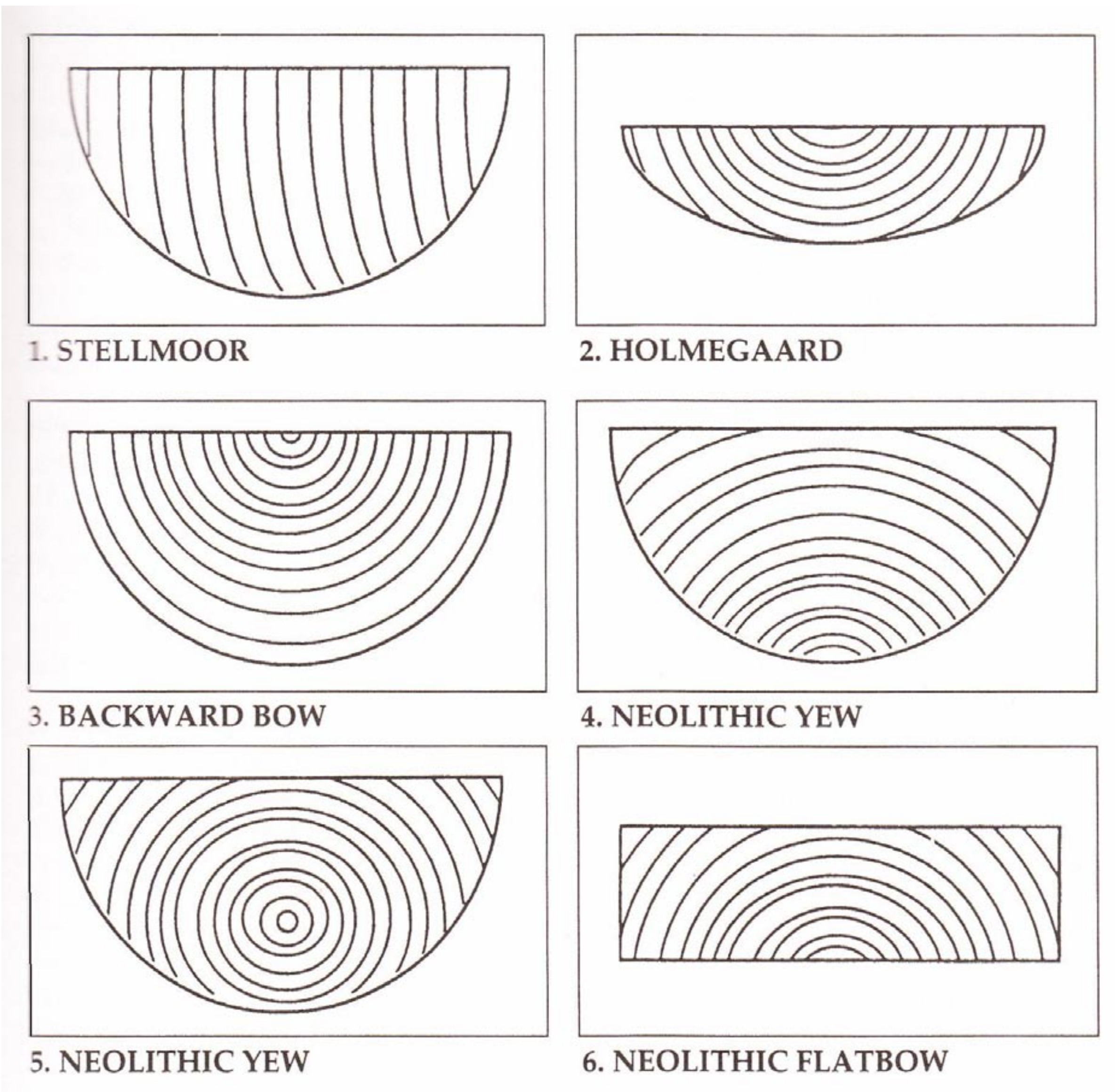


Figure 1.6 Cross sections of prehistoric bows. Backs face upwards. Note the orientation of the growth rings in relation to the back of the bow. All of these earliest European forms have

exposed rings on the back (Reproduced with permission from Bois d'Arc Press, adapted from Comstock 1993: 91).

There are numerous other Neolithic bows that have been recovered in Europe (Comstock 1993; Clarke 1963; Rausing 1967); however, there are three that are particularly noteworthy. The first and oldest is dated to 5300 BP and was found with the "Iceman" in 1991 in a melting glacier at 10,500 feet in the Tyrolean Alps on the Italian-Austrian border. It is made from yew with a "D" cross-section and in profile is typical of Neolithic bows that do not have a rigid handle section (Spindler 1994). The next two bows of concern are somewhat famous among archery historians. They are both yew selfbows with well-defined handles from Somerset, England and while found within a mile of each other in peat bogs and dating to the same time period they are markedly different from one another. Slightly the oldest is the Meare Heath, which dates to ± 4690 BP, and the Ashcott Heath dates to ± 4665 BP (Clark 1963). Only half of each bow was recovered, the Meare Heath specimen measures to 100 cm (39"); assuming that the bow was symmetrical the total length would have been 190.5 cm (75"). The surviving portion of the Ashcott measures 83 cm (32"); the assumed symmetrical length would have been 159 cm (62.5"). The two bows differ significantly in that the Ashcott would have been approximately 30-cm. (11.5") shorter than the Meare Heath and moreover the latter possesses an elaborate webbing and binding of the limbs, which is unique among prehistoric bows of Europe. Clark (1963) contends that this was necessary for reinforcement due to the extreme width and thinness of the limbs, which are 3.5 times wider than the Ashcott. The Meare Heath is "by far the thinnest of the whole prehistoric series" reviewed by Clark (1963: 56). The variation between these two bows is intriguing given their geographic proximity and near contemporaneity. This serves to illustrate that there was considerable diversity in the size of bows even at this early date (For in depth reviews see Clark 1963; Comstock 1993; Rausing 1967).

Outside of the European continent in the Old World there is scant published information regarding the appearance of the bow in terms of actual archaeological specimens. In the Near East, Asia and China, the composite bow was widely in use by approximately 4500-4000 BP but its origins are not clear (Cattelain 1997).

New World Archaeology

Hamilton (1982; 13) contends that the bow appeared in North America 2000 years ago at the earliest while somewhat similarly Blitz (1988) contends that it appeared in the Northern Plains of Saskatchewan and Alberta 1800 bp or slightly earlier. Both of these opinions are based on the appearance of small light stone projectiles assumed to be arrow points. This subject will be addressed fully in the Chapter 2 on the Identification of the Weapon Systems. The oldest excavated bow recovered from North America is from a burial at the Mounds Plantation site in Louisiana. The estimated age, based upon two radiocarbon dates, is 930-950 bp (Webb and McKinney 1975). Culturally, it is associated with the Alto-Gahagan focus, Gibson aspect (Early Caddoan) and is made from Osage orange (*Maclura pomifera*). It is a "D" bow in profile, 167 cm long (66"), with recurved tips. It is noteworthy that the bow is a recurve at this relatively early date. Story (1990) indicates that the bow and arrow was introduced to this area around 1250 bp and this bow is evidence that recurve technology was in use within at least 300 years after adoption of the weapon.

There are two prehistoric bows from Texas that are relevant to the study. The first, known as the Perrin bow was recovered in Terrell County, about one mile north of the Rio Grande in the Trans Pecos region (Weiderhold et al. 2003). A wood sample collected from the specimen yielded a radiocarbon age of 545 ± 40 bp. It is constructed from little-leaf walnut

(*Juglans microcarpa*) and the length from tip to tip is 162.5 cm (64”). It is a simple “D” bow and its most interesting characteristic is that the limbs are substantially deflexed, indicating that they are bent towards the belly of the bow or the archer. Most selfbows have some degree of deflex with about 4 cm (1.5”) being somewhat common; however, this specimen has 10 cm. Weiderhold et al. (2003) contends this extreme amount is due to the lack of large suitable trees for bow construction in the xeric environment. The bow is similar to deflexed bows used by the Mojave Indians in the southwest. Low moisture content combined with weak, brittle wood necessitate the low-strain deflex design (Baker 1994).

Several attributes of the bow indicate that the bowyer had advanced experience in bow construction. First is the aforementioned deflex design, second is the tapering of the limb tips or knocks, which reduce limb mass and increase arrow velocity (Baker 1994). Third is the care with which the bowyer scraped the knots on the back of the bow to allow for extra strength in a failure prone area. Further evidence of the bowyer’s knowledge is that the lower limb has been repaired with a sinew and or rawhide wrapping. Lastly, Weiderhold et al. (2003) state that due to the age of the wood and rodent gnawing it is not possible to determine whether or not the bowyer followed a single growth ring down the back of the bow as was discussed in the previous Old World section. However, it appears that the bow was primarily shaped by removing wood from the sides and belly, thereby saving wood on the back. This is essential if the bow is constructed from a small limb or sapling, such as this bow, and also implies an intimate knowledge of bow construction principles.

The second bow called the “Knight bow” is also from a cave in the Trans-Pecos region of Texas. Although dated to 190 ± 40 bp in the Historic period, it is included here because it is an archaeological specimen and its shape and method of manufacture are strikingly similar to the previously discussed Perrin bow (Weiderhold et al. 2003). A distal portion of one limb is missing and thus the estimated length is 137 cm (53"), which is around 40 cm (16") shorter than the Perrin bow. The two bows are both quite similar in width with the former being 2.5 cm at the handle while the latter is 2.6 wide at the handle. As with the Perrin bow the Knight bow is a deflexed selfbow made from a small limb although it is not possible to determine the species in this case. Both were constructed using the same method of reducing the sides and belly, with the back of the bow being the outer bark side of the tree. The Knight bow also has features that indicate the maker was experienced. For example, the knots on the back of the bow were raised leaving extra wood in an area destined for failure if not crafted meticulously. And the bow exhibits signs of possible repair with glue although it is not clear if this repair was prehistoric as it was donated to the University of Texas before 1936 (Weiderhold et al. 2003; 96). There is one major difference between the bows, and that is that the Knight Bow is recurved on the extant tip. This is a slight recurve and would have provided only a modest gain but it is an attempt to improve efficiency. It is noteworthy that both of these selfbows exhibit a "D" profile, which would be difficult to mistake as a "Turkish" bow. Cabeza de Vaca passed through the Trans-Pecos region following the Rio Grande around 1542 A.D. (de Vaca 1907) and the Perrin bow, dated to 545 ± 40 bp, is slightly older than the expedition and was found a mile north of the river (Weiderhold et al. 2003: 90). The Knight bow, although substantially younger, was found in a cave in Presidio County, sixteen miles southwest of Marfa, and was within several miles of the north of the mouth of the Conchos River where it joins the Rio Grande. At this junction in 1582-83 A.D., Diego Perez de Luxan accounted that they traded with the Abriaches Indians for "bison skins, and Turkish bows reinforced with sinews. These are the best and the strongest which there are in the land that has been discovered" (Hammond and Rey 1929: 126). The archaeological evidence of the Perrin bow being dated to 545 ± 40 bp combined with the eyewitness accounts of the Spanish suggest that there were at least two types of bows in use at the time of European contact.

Performance Characteristics Comparison

The chronological trend of the bow and arrows replacement of the atlatl will be fully addressed in the Chapter 2 on the Identification of the Weapon Systems. In short, Blitz (1988) surmises from the advent of small light bifacial projectiles that the bow and arrow first appeared south of the boreal forests around 1800 bp in the Great Basin and Intermontane West and the Northern Plains of Saskatchewan and Alberta. From there it quickly spread southward reaching the Panhandle of Texas around 1400 bp, and the north central Texas region around 1250 BP (Ferring and Yates 1997, 1998; Story 1993; Prikryl 1990). He further postulates that the rapid spread of the bow and arrow across diverse ecological zones indicates that it was the result of diffusion rather than episodes of independent invention, and as Hughes (1998: 393) notes, the virtually complete replacement of the atlatl in North America implies that the bow duplicated and more successfully carried out the functions of the atlatl. However, as Blitz (1988: 133) suggests it is an “implicit assumption that the bow is a technological advance over the atlatl.” Indeed, physically or mechanically determining which weapon system is more efficient is fraught with difficulties and should be addressed.

A reasoned comparison between the efficiencies of atlatls and bows and arrows must take into account several factors. First of all, what is being compared? There are no known performance standards of prehistoric weapons that were launched by people using prehistoric methods of shooting or throwing. The abilities of modern users may not reflect the abilities of prehistoric people, especially in regards to the atlatl. For instance, Browne (1940: 211) provides a prime example of how the *perceived* efficiency of the weapon sometimes relates to the capabilities or prejudices of the researcher when he states that "any degree of accuracy is impossible with the atlatl and the spear" after he admits that following 6 months of practice he still could not "hit a buffalo 1 out of 10 times at 30 yards". Butler (1975) and Patterson (1977) had a similar lack of success; however, other modern atlatl enthusiasts record much greater prowess in accuracy and efficiency hunting (Whittaker 2005: 21). Similarly, Frison (1989) demonstrated that a Clovis point on a dart launched by an atlatl could deliver a potentially lethal wound to a dead elephant carcass. These cases illustrate the fact that there is considerable disparity in the assessment of spearthrower effectiveness (Hutchings and Bruchert 1997). However, the atlatl certainly was effective in the hands of prehistoric people or it would not have been employed for thousands of years with near global distribution. This does illuminate the problem, in that it is difficult to determine the prehistoric efficiency within the spearthrowing system itself, much less between the atlatl and the bow and arrow.

Another factor influencing the assessment of efficiency between the atlatl and the bow and arrow is that there are very few, if any, surviving archaeological specimens of actually complete projectile delivery systems (e.g. the bow and arrow with point or the atlatl and dart with point). The stone point is most often the only surviving part and there is often debate as to which attributes will accurately identify it as a dart or arrow point (Binford and Papworth 1963; Bradbury 1997; Browne 1940; Christenson 1986; Corliss 1972, 1980; Fawcett and Kornfield 1980; Fenenga 1953; Forbis 1960; Hamilton 1982; Nassaney and Pyle 1999; Odell 1988; Patterson 1985, 1992, 1994; Shott 1993, 1997; Thomas 1978; Wyckoff 1964). While some researchers have used attributes of it as proxy measures for changes in the overall weapon system (Hughes 1998), it is only one part of a system and anything else has to be inferred. Darts are calibrated to spearthrowers in terms of their length and stiffness, arrows are tuned to bows in regards to their spine, and without the whole system it is difficult to ascertain the capabilities and prehistoric efficiency of the weapon.

There are museum specimens that have been tested for performance. Pope's (1923) often-cited study utilized Native American bows, without accompanying arrows, from the University of California, the Jessop, and the American Museum of Natural History, was a worthy attempt, especially at the time. However, the advanced age, infirmity, and lack of companion arrows with the weapons should call into question whether these were truly representative their prehistoric performance. One bow actually broke during testing and others were modified in an attempt to gain efficiency.

Additional caution should be used when comparing or evaluating weapons out of the context of their intended use. Early assessments of the bow were comparisons to Old English archery equipment and shooting standards evolved from the longbow (Hamilton 1982). The vast majority of Native American bows were designed for close range encounters, unlike many Old World bows that were shot from tens or hundreds of yards. There is little to be gained from determining the maximum killing distance of a Yahi bow such as Ishi's because it was used for close range ambush hunting along trails. Ishi's type of bow would not have won many wars in Europe, and a 70" English longbow would be impractical, if not impossible, to shoot from a kneeling position in dense brush in California. Any valid evaluation or comparison of the atlatl and the bow and arrow must view the weapon in the context of their intended use to have meaningful scientific value.

In summation, the difficulties in comparing the difference in performance weapon systems are numerous and substantial. Issues such as, bias or athletic capability of the researcher, lack of surviving complete prehistoric weapon kits, and evaluating weapons out of context should not preclude the comparison of the atlatl and the bow and arrow but are instead examples of the difficulties in reaching a steadfast or unequivocal conclusion on which is more efficient in the prehistoric context.

In spite of the difficulties in comparing the weapon systems there has been considerable debate over which was more effective. Some contend that the atlatl possessed a number of advantages in certain contexts, such as hunting from boat, (Dickson 1985; Hutchings and Bruchert 1997; Kellar 1955); however, most indicate that the bow was superior for a number of reasons (Blitz 1988; Cattelain 1998; Farmer 1994; Hughes 1998; Hutchings and Bruchert 1997; Raymond 1986). A variety of categories have been used in these evaluations and they can be divided into two fundamental groups: (1) actual mechanical or physical parameters such as velocity, throwing distance, and kinetic energy, which can be quantified, and (2) a more qualitative or subjective category that Hughes (1998: 393) describes as “desirable situational characteristics” which are an assessment of the versatility of the weapon system and would include characteristics such as; rate of fire, transportability, concealment or amount of motion required. As stated these are somewhat subjective, in that, some characteristics such as the rate of fire would depend on the skill of the individual. Both of these groups are shown in Table I, to facilitate comparison. The categories in the first group such as velocity and distance will be discussed separately while the categories of the second group will be discussed together. The background information is derived from experimental archaeology, and ethnohistorical and ethnographic literature. If a weapon system possesses a distinct advantage as indicated by the physical evidence or the literature it will receive a plus in that category. If there is no clear distinction, an equal sign will be indicated. The basis for these conclusions is provided in the following discussions.

Table 1. Physical/Situational performance comparison. Note the superiority of the bow and arrow when compared to the atlatl.

	Atlatl	Bow
Distance		+
Velocity		+
Accuracy		+
Kinetic Energy	+	
Rate of Fire		+
Concealment		+
Closed Environment		+
Open Environment	=	=
Portability		+
Number of Projectiles Carried		+
Durability	=	=
Weather Dependency	+	
Total	2	8

Physical Comparison

Distance

A number of researchers have investigated the maximum-throwing distances of the atlatl (Hutchings and Bruchert 1997; Raymond 1986) and the bow and arrow (Hamilton 1982; Pope 1923). Tests indicate that a dart can be thrown over 100 meters (Bassett-Smith 1909: 328; Palmer 1884: 287), at least three to four times as far as with bare hands (Dickson 1985) and most prehistoric bows could shoot over 100 meters as well (Pope 1923). While these examples provide a sense of the potential distance that the weapons are capable of, prehistoric weapons primarily used for subsistence were employed at as close a range as possible (Mason 1886). Thus, maximum-throwing distances are not representative of the method in which the weapons were used, but they do illustrate that both the atlatl and the bow and arrow were capable of launching projectiles in excess of 100 m. In light of this, the focus here will be on the actual or effective distances that the weapons were employed and the associated advantages.

With the exception of the English longbow (Hamilton 1982), which was used for hunting at considerable distances in broad gallery forests, and some atlatls that were used for waterfowl (Stirling 1960), prehistoric weapons used for subsistence were employed at close range to increase accuracy. Cattelain (1997: 218) reviewed several sources in Australia and found that distances for accurate throws with the atlatl at immobile targets were over distances ranging from 45 to 55 m. However, emus and kangaroos were usually ambushed near water sources where the darts are thrown from distances between 15 to 20 m. Spencer and Gillen (1899:20) indicate that only a very skilled hunter could kill game at more than 20 m. This is in contrast to Darwin's (1909: 457) account in 1836, near Bathhurst, Australia where he viewed Aborigines casting darts. "In their own arts they are admirable. A cap being fixed at 30 yards distance, they transfixed it with a spear, delivered by the throwing-stick with the rapidity of an arrow from the bow of a practiced archer". Given Darwin's reputation as a precise observer this representation seems plausible, unlike some other historical accounts. Also, it corroborates evidence from North America, where Nelson (1899: 152) states that small, light spears used for seal hunting were cast from 27 to 45 m with "considerable accuracy and force", and furthermore that their accuracy was "remarkable" when practicing by throwing at waterfowl, sometimes in excess of 25 m. Still, with these accounts there is no reliable scientific data, in that a quantification of hits per shot fired would be much less subjective than someone's opinion of what constitutes an accurate shot. Summarily, the evidence indicates that prehistoric shots with the atlatl were generally less than 25 m and were likely closer to 18 m. (Blitz 1988; Hughes 1998).

From a global perspective, there are certainly examples of bows that can launch arrows considerably farther than a dart can be thrown. The long-range exploits of the English longbow have been well documented and some Turkish hornbows could regularly shoot arrows in excess of 400 m (Rausing 1967). These bows were primarily designed and used for warfare at considerable distances and are in direct contrast to the North American composite hornbows used for bison hunting that were shot point blank from a distance of a few meters on horseback (Hamilton 1982). In fact, most bows used in the New World were designed for close range hunting and most conflicts were conducted at considerably shorter distances than in Europe or Asia. Therefore, the effective distance of the weapon must be viewed in the context of its usage.

Pope (1923) documented maximum throwing distances for a variety of North American prehistoric bows and all of them had a cast that fell between 30 and 185 m, the average being 160 m. In actual hunting situations, Pope (1925) observed that Ishi's varied from 9 to 45 m and that he could regularly hit a target the size of a quail at 25-35 m. However, his accuracy decreased considerably at distances greater than 45 m. Ethnographically, Spier (1928) found that the effective range among the Havasupai was also around 30 to 45 m. Interestingly, he states that at that range they could penetrate a deer 15 to 25 cm. which would not seem to be that effective given that a minimum of 20 cm of penetration is required to dispatch large ungulates (Friis-Hansen 1990). Thus with considerations of accuracy and penetration this evidence indicates that the farthest effective range generally employed with Native American bows was around 35 m and that most successful shots were taken at 25 to 35 m (Butler 1975; Friis-Hansen 1990;

Hitchcock and Bleed 1998; Hughes 1998; Langenau 1986; O'Connell and Hawkes 1988; Rausing 1967).

In summation, the maximum distances that can be achieved with the bow are substantially greater than with the atlatl but there is only a slight improvement in effective distance between the two, with the atlatl being around 18 m and the bow at 25 to 30 m. The bow and arrow are given the advantage in Table I.

Velocity

The greater distance achieved by the bow and arrow over the atlatl is a product of greater velocity. Hughes (1998: 352) indicates in a study of ethnographic specimens and replicas that the mean velocity of the bow and arrow is approximately twice that of the atlatl, from 78 to 154 fps (46.9 to 23.6 mps). Thus, the bow and arrow are given the advantage in Table I.

Accuracy

Theoretically, greater accuracy will be achieved by the bow and arrow because of increased velocity and thus flatter trajectory of the projectile. Essentially the user does not have to adjust their point of aim due to the arc of the projectile. Some have also postulated that the bow is more accurate because it is back-sighted (Christenson 1986). The bow and arrow are given the advantage in Table I.

Kinetic Energy

This is the only physical category in which the atlatl has a demonstrable advantage. The dart weighs roughly three times as much as the arrow; this increase in mass results in more kinetic energy. Hughes (1998: 352) calculates in a study of ethnographic specimens and replicas that the mean kinetic energy for the arrow group was 29.5 while there was modest increase to 32.5 for the dart. Thus, the atlatl may have been more useful for large prey due to the greater weight of the projectile, just as modern gun hunters use larger caliber weapons for larger prey such as elephants. There is archaeological evidence that supports this claim on the Columbia Plateau. Here the atlatl was still in use for at least a thousand years after the introduction of the bow and arrow (Galm et al. 1981; Leonhardy and Rice 1970) at around 2200 bp. Some contend that this was the result of the atlatl being preferentially selected for large game (Brauner 1976; Chatters et al. 1995; Schalk and Olson 1983). Chatters et al. (1995: 761) more specifically state "during the first few centuries after the bows adoption, it lacked the impact power necessary to penetrate the hide of larger thick-skinned species, necessitating the retention of the atlatl for that purpose". It is clear the atlatl and dart possess an advantage in comparison to the bow and arrow in the terms of kinetic energy and are given the advantage in this category (Table 1).

Situational Comparison

Rate of Fire

Although the dart can be propelled by the atlatl with a quick flick of the wrist, side-armed or overhead with the traditional arcing motion, Frison (1978: 228) and Raymond (1986: 171) assert that it that it requires more motion than is necessary to simply draw a bow and release an arrow. Christenson (1986) contends that the bow and arrow allow a higher rate of fire due to this reduction in motion. And though there are few accounts of the speed in which the atlatl was used, there are numerous accounts of archers launching arrows at incredible rates (Catlin 1973;

Hamilton 1982). The bow and arrow receives the advantage in the Rate of Fire category (Table 1).

Concealment and Closed Environments

Less motion to launch an arrow also provides more Concealment. Without the high arcing motion of the atlatl the bow is easier to use in brushy or Closed Environments (Cattelain 1998). Thus, the bow receives the advantage in these two categories (Table 1).

Open Environments

Cattelain (1998) asserts that the atlatl is principally used in Open Environments such as desert, steppe, prairie and aquatic areas (lake, sea or river); however, there is plenty of evidence of the bow and arrow's effectiveness in this realm as well. It is widely demonstrated in warfare in Europe and Asia, and in hunting on the plains in North America. In light of this, neither weapon is deemed to have a clear advantage in an Open Environment (Table 1).

Portability and Number of Projectiles Carried

The bow and arrow are more portable due to the greater length and awkward nature of the darts. Some darts approached 7' in length and carrying a number of those would be difficult, especially in dense brush. Some contend (Hamilton 1982) that detachable foreshafts were commonly used which would ensure that fewer main shafts would have to be carried. In contrast, as many as 50 arrows could be carried in a quiver without affecting movement, and the hands would be free to use the bow. The bow and arrow receive the advantage in Portability and Number of Projectiles Carried (Table 1).

Durability

Durability of prehistoric weaponry is not an easy issue to assess. There does not seem to be any accounts of the life expectancy of the atlatl and information on the bow and arrow are scant. It could be assumed that the bow and arrow would require more maintenance since there are more parts and the inherently fragile nature of the bowstring itself would necessitate that this system was less durable in a strict sense. Most importantly, the durability of the weapons must be assessed in the context of the total weapon system and not just the bow or the spearthrower.

Due to the fact that an atlatl is small enough that a spare can be carried, and one can be constructed in a day, the issue of durability is not as critical as it is with the bow. It is not common to carry a spare bow and manufacture times can require at least several hours for an expedient or "quickie" bow as opposed to an atlatl. Ethnographic accounts of the Siriono (Holmberg 1950) of Eastern Bolivia indicate that a bow may last a year or more; however, they do not make a new one until the old one is unusable. Strings are the considered the weak link although they are readily constructed. Furthermore, Rausing (1967) indicates that there are composite bows that have lasted for decades. Therefore, it would seem that while the bow may require more initial investment it could last for months if not years. Conversely, the spearthrower may not last as long but is readily constructed from almost any wood, antler or some bones. Thus it is clear that durability must be viewed in the context of the weapon system. And being that it is a system the projectiles must be considered as well.

Both darts and arrows can be designed to sustain multiple firings; however, the more robust structure of the dart suggests it would be more durable. They are somewhat *overdesigned* (Bleed 1986) in comparison to the arrow, in that the stone points are large enough that they can be reworked if damaged. Most arrow points are simply too small and delicate to be reworked if damaged; however, they could be resharpened. Furthermore, darts utilizing a foreshaft could secondarily be used as knives implying more durability (Allchin 1966: 160; Moseley 1877: 407). Hamilton (1982: 15) contends that darts utilizing a detachable foreshaft were intended to allow the hunter to retrieve the mainshaft and fire it repeatedly. It is here posited that the dart can be viewed as a curated projectile system (cf. Binford 1979). The mainshaft, the foreshaft and stone point were designed to be recycled and sustain multiple episodes of propulsion. Though there are some groups that reuse arrows (Holmberg 1950; Bleed and Hitchcock 1997) there is little evidence globally that they were intended to be fired on multiple occasions, or that they were secondarily used as knives (Ellis 1997).

In comparison to the dart, the arrow is an expendable projectile technology, which was primarily designed for a single use. This is indicated by fundamental differences in construction related to size and robusticity, as well as a lack of evidence of the use of arrows with a detachable foreshaft. Carrying a large number of expendable arrows, as opposed to a few recycled darts solved the issue of projectile durability. As with the spearthrower and bow, the durability of the dart and arrow must be viewed within the context of the weapon system because the issue was resolved in such vastly different ways. The two systems are deemed equal in this category Table 1. This issue will be investigated more fully in Chapter 4 in the section on Use, Maintenance, and Discard.

Weather Dependency

The atlatl has the advantage in terms of Weather Dependency (Table 1), if for no other fact, than that the bowstring is at least modestly affected by moist weather if made from vegetable fibers, and drastically affected if made from sinew. A bow can lose ten or more pounds in draw weight if the string stretches. There are accounts of Natives in North America suspending conflicts until dry weather resumed. Additionally, wooden selfbows can lose weight if they absorb too much water and sinewback bows can completely deconstruct in moist weather. Kellar (1955) notes that the atlatl was still employed by Eskimo groups and the Aztecs, both of which still hunted from watercraft at the time of European contact. Besides the moisture resistant nature of the atlatl, it also leaves a free hand to steer the watercraft. The atlatl is given the advantage in the Weather Dependency category (Table 1).

Summation

The results of the Physical/Situational Performance Characteristics comparison reveal that the bow and arrow is more effective in eight out of twelve categories (Table I). More specifically, in the Physical Comparison it has a distinct advantage in terms of distance, velocity, and accuracy while the atlatl has the advantage in kinetic energy. This indicates that projectile mass was not as important as projectile speed and increased accuracy to prehistoric users. Essentially they selected the weapon that provided them with the highest probability of striking vital organs, as opposed to one that offered the greatest depth of penetration. With low velocity weapons that kill by inflicting hemorrhaging, it is evidently more advantageous to be on target, than have deeper penetration in an area that is non-lethal. All Native American hunting methods such as ambush, stalk, pounds, and drives, were attempts to close the distance to game to increase accuracy (Mason 1893), especially the universal techniques of luring animals in through calls, decoys or mimicking by wearing skins (Catlin 1973; Hamilton 1982; Pope 1918; Speir 1928; Swanton 1942). In comparison to the atlatl, the bow and arrow was a further attempt to increase accuracy as well.

The Situational Comparison reveals that the bow and arrow has an advantage in: rate of fire, concealment, closed environment, transportability and number of projectiles carried, while the weapon systems are equal in the categories of open environment and durability. Taken as a group, these essentially demonstrate that the bow and arrow is more versatile (Hughes 1997) or situationally flexible. Contradictions in the literature indicate this as well, with several researchers contending that the bow and arrow were better suited to small game (Chatters et al. 1995; Ellis 1998; Hitchcock and Bleed 1997; Pope 1925) while others postulate that it was employed for large game (Catlin 1973; Speir 1923; Swanton 1942). It was distributed globally with the exception of Australia and Polynesia, and used in all types of terrains from dense forests, jungles, steppes, prairies, plains, to deserts and arctic. It was not primarily suited to any particular task, as it could be employed in the pursuit of almost any game, in any environment. The essence of hunting, is adapting to the habits of the prey and environmental conditions and the bow was simply more adaptable than the atlatl.

Finally, the transition from the dart to the arrow may be more significant than the transition from the spearthrower to the bow. Besides the fact that darts are less portable than arrows (Cattelain 1997; Nelson 1997), the change to the arrow signaled a fundamental shift in the relationship between the hunter and their projectile. The traditional view of the atlatl is that hunters would carry only one or very few mainshafts and that they would have several foreshafts. After an animal was hit, the dart was designed so that mainshaft would detach and it could be retrieved and resocketed with another foreshaft. The hunter, in a sense was tethered to the retrieval of the remnant foreshaft. Thus at this critical juncture, when a dart has hit an animal, the hunter would have to concern him or herself with finding the mainshaft, instead of pursuing wounded game. Ethnographic evidence indicates that the tracking of wounded game, and retrieval before scavengers, is one of the, if not the most important, variables in hunting success (Bartram 1997; Hitchcock and Bleed 1997). The self-arrow, without a detachable foreshaft would have allowed the hunter to immediately pursue game or nock another arrow and fire again. In summation, the expendable arrow technology, in which a large number of arrows were carried in comparison to a few recycled darts, provided increased flexibility in the pursuit of game and may have resulted in a higher success rate. The arrow, as with the bow, was simply a more versatile weapon.

CHAPTER 2

IDENTIFICATION OF THE WEAPON SYSTEMS

To conduct a comparison between the technological efficiencies of the Late Holocene inhabitants of north-central Texas that used the atlatl and those that used the bow and arrow it is imperative that they can be identified in the archaeological record. There are no known archaeological specimens from the area, and beyond actual specimens such as those discussed in the sections on Atlatl Archaeology and New World Archaeology of the bow, the presence of, or transition to the bow and arrow has to be inferred. Indeed, short of direct association with the propulsive device, designating a stone tip to either a dart point or an arrow point is an assumption.

There has been a long held premise that the spearthrower preceded the bow and arrow in the Old World (Garrod 1955; Mason 1928), and in the New World (Cushing 1895; Mason 1928; Pepper 1905). As such, early archaeologists in North America (Baker and Kidder 1937; Kidder 1938; Fenenga 1953) attempted to explain the abrupt appearance of small, light projectiles in the archaeological record as the introduction of the bow and arrow. This was based on the fact that large points dominate older assemblages and that there is an apparent total absence from all "respectively ancient deposits of small, light points suitable for the tipping of arrows" (Baker and Kidder 1937: 51). Furthermore, the large points found in later deposits such as Pueblo sites were "set in short handles for use as knives, but never in arrows" (Kidder 1938: 156). Essentially they contended that the arrow required a much lighter projectile than a dart propelled by an atlatl or thrown by hand. Browne (1938, 1940) tested this small-point, large-point dichotomy using both the atlatl and bow and came to the conclusion that large points could function on arrows; in fact, he and Amick (1994) contend that Folsom points could have been well suited to arrows.

Other research supports that there is a great deal of allowable variation in point size that can be utilized with the weapons (Couch et al 1999). The author's hunting experience supports this as well, having shot 8 whitetail deer with metal arrowheads that weigh 8.7 grams, and 2 others with stone tips that weigh in excess of 4 grams. These were dispatched with selfbows and sinew-reinforced bows that are well within prehistoric parameters in terms of draw weight (48lbs. to 58lbs.) and size (48" to 64"), They were also constructed from a traditionally used wood, Osage orange (*Maclura pomifera*) (Fig 2.0). Only in neck width and neck thickness would these points be strictly considered arrow points, all other attributes such as weight, length and width could be considered dart point in size. Additionally, there are numerous Native American arrows catalogued in museums that are tipped with metal trade points from Europe that do not conform to archaeological expectations of what constitutes an arrow point (Allely and Hamm 1999; 2002). This is not to contend that prehistoric hunters who used the bow and arrow employed stone tips that were relatively "large" or "heavy"; however, it does serve to illuminate the complexities in determining with certainty, what defines a dart point or an arrow point. And it illustrates that there is an overlap in the size, and especially in the weight, of projectiles that can be used to tip the dart or arrow. It is obvious they *chose* to use small "bird points" because they are not a prerequisite. Penetration studies utilizing large and small stone tips with each weapon system could point towards a resolution of the reason that small, light points were employed when points literally three times as heavy could have been used. However, the fact that there can be potential overlap in the tip size of the projectile systems does not preclude distinction between the two in the archaeological record. This is only what is possible from a mechanical or physical perspective and is likely not optimal in terms of performance. Albeit that the view that "small points" are arrows and "large points" are darts is assumption; ethnographic evidence and the mechanics of aerodynamics suggest that arrows are generally smaller and lighter than darts (Christenson 1986; Patterson 1982; Thomas 1978).

Figure 2.1. Osage orange bow and cane arrow constructed by the author. The bow is 58 lbs. at a 24 in. draw and was used to dispatch two whitetail buck deer.

There have been a multitude of attempts and approaches to formally distinguish between stone dart and arrow points, and research indicates that they can be seperated on the basis of discrete metric variation (Bradbury 1997; Corliss 1972, 1980; Fawcett 1998; Fawcett and Kornfield 1980; Fenenga 1953; Hughes 1998; Nassaney and Pyle 1999; Patterson 1982, 1985, 1992; Shott 1993, 1997; and others). Thomas's (1978) oft-cited study utilized dimensions from ethnographic and archaeological specimens across North America to derive classification functions that could be used for taxonomic purposes. This approach has been applied to points from various regions (Bradbury 1997; Knight and Keyser 1983) and other variables have been used (Patterson 1985). And yet other researchers have increased the sample size and attempted to redefine the discriminant functions using fewer variables (Shott 1997; Bradbury 1997). In most areas the statistical discrimination indicate that dart and arrow points compose discrete groups (Fawcett 1998; Lynott 1975) and most of the variables graphically exhibit a bimodal distribution.

Neck Width and Neck Thickness

At least as far back as the early 1960's (Forbis 1962; Binford and Papworth 1963; Wyckoff 1964) researchers noted that neck width and to a lesser extent neck thickness (Hamilton 1982) may be the most discriminating variables in distinguishing between dart and arrow points. Essentially these variables are most closely controlled by haft requirements as they correlate with the diameter of the dart or arrow shaft. In a uniformitarian sense, just as the fracture mechanics of stone remain under the same constraints in the past as they are now (cf. Faulkner 1972), so are the flight performance requirements of the spearthrower and dart and the bow and arrow. These requirements constrain the dimensions of the dart and arrow shafts.

Flight mechanics necessitate that arrow shafts must be of sufficient stiffness not to shatter or splinter while under the stress of propulsion (English 1930) and they must also possess sufficient flexibility to be capable of "bending around the handle of the bow." This phenomenon is known as the *Archer's Paradox* and is a significant problem in archery (Klopsteg 1943: 187). As the arrow rests on the string of a prehistoric bow it is generally not oriented straight forward due to the obstruction of the handle. (Modern bows have a sight window cut out of the handle and are thus center shot). Therefore the arrow is forced to arch around the handle as the energy is transferred from the bow. Slow motion photography show arrows actually bent in flight. If the spine is too limber the arrow will over flex, resulting in a shot to the right or even breakage. If the spine is too stiff the arrow will not flex sufficiently causing the arrow to strike the handle as it passes and veer to the left. Thus there are limits to the flexibility, and more importantly for this discussion, the stiffness of the arrow. It is unlikely that arrows on the smaller end of the spectrum would be confused with darts; however, larger, stiffer arrows and small darts could overlap in size.

Although the dart has spine requirements (Hughes 1998; Perkins 1992) it is not under the same constraints as the arrow. The force initiated at the butt end of the dart generates three transverse oscillating waves that travel the length of the shaft, return, and travel back to the tip as the dart is accelerating. The stored energy of the waves launches the dart away from the spearthrower. Obviously in this process the dart is not required to bend around the handle as with the arrow and the Archer's Paradox. This allows the dart to be considerably larger and thus stiffer than the arrow potentially approaching thrusting spear size (Hughes 1998). The inherent differences in the launching processes between the dart and arrow determine the allowable amount of flex in the spine. In turn, these restrictions place limits on the size of shaft dimensions within these weapon systems and these directly correlate to the neck width and neck thickness of the projectiles. Other metric attributes such as length, width, weight, maximum thickness, blade length and tip cross section are controlled by shaft size and as such, are pleiotropic variables (Hughes 1998: 345). The values of these "riders" are often a reflection of resharpening (Frison 1976) or retooling (Keeley 1982). The attributes that are least likely to change are neck width and neck thickness and these are also not as influenced by cultural preferences. For these reasons, neck-width will be the primary justification for the transition to the bow and arrow in north central Texas.

Chronology

It is generally accepted that the atlatl was widely distributed in North America during the Late Archaic and that by the time of European contact in the sixteenth century the bow and arrow had virtually replaced the longstanding technology. There is considerable debate about when and how this transition was effected. Most researchers contend that the bow and arrow were diffused from Asia along with pottery and burial mounds (Browne 1938; Blitz 1988; Chard 1969; Massey 1961). While New World antecedents have been found for the latter two, there is little evidence that the bow and arrow were independently invented in North America. As discussed in Chapter 1, the oldest known specimen of a bow is the Mounds Plantation bow (Webb and McKinney 1975) dated to 950 BP; however, most all researchers agree that it was in use several hundred years earlier. Its presence is indirectly inferred by the presence of “small” stone points and microliths. Thus, researchers can come to differing conclusions on the chronology depending on their view of what constitutes an arrow point. This discussion will review the traditional model for the chronology of the introduction generally following Blitz (1988) while pointing out contrary evidence.

The earliest possible evidence comes from the Arctic where a microblade technology was in use at 11,000 to 8,000 BP (Blitz 1988). This is associated with the Arctic Small Tool Tradition and may be paralleled with Old World Mesolithic and Paleolithic usage as arrow barbs on composite arrows. However, the first clear evidence of the bow only occurs after 5000 BP in the western Arctic with later dates occurring progressively to the east.

Blitz surmises from the archaeological evidence that small bifacially flaked arrow points replaced the microlith arrow barbs of the Arctic and Old World before the bow appeared south of the boreal forests. Furthermore, he contends that the earliest evidence of the bow south of the boreal forests occurs at around 1800 BP in the Northern Plains of Saskatchewan and Alberta and in the Great Basin and Intermontaine West. This is contrary to early evidence of the bow the on the Columbia Plateau at around 2400 BP (Schalk and Olsen 1983) and certainly by 2100 BP (Chatters et al 1995). These would be the earliest dates in the U.S.

In other regions of North America, including the Great Lakes, Northeastern Woodlands, the Midwest and Southeast, and the Plains, the preponderance of the evidence indicates an introduction of 1500 BP or later for the adoption of the bow (Blitz 1998; Weiderhold et al. 2003). In Texas, the earliest signs are associated with violence and are located in the Panhandle region at the Dykema burial with a date of around 1,290 ± 40 BP (Wilkens 2001). Blitz cites separate works by Aten (1984) and Hester (1977) that propose dates of 1500-1400 BP for the Upper Texas Coastal Plain and 800 BP for South Texas and the Rio Grande, respectively (Blitz 1988: 127-131). Prewitt (1983) indicates with radiocarbon evidence that corner-notched Scallorns and Austin Phase diagnostics move from north to south across the central part of the state at around 1200-1300 BP. This is in accordance with dates from the north central Texas area at around 1250 BP (Ferring 1997, 1998; Prikryl 1990; Story 1990).

Abrupt or Gradual Transition

The traditional model expressed by Blitz (1988) contends that although the bow was used for several centuries in the Arctic, once it was south of the boreal forest its spread was rapid from north to south implying diffusion. This view is based on the point size as the primary indicator of the advent of the technology; however, there is some contrary evidence. Notably, Shott's (1994, 1996) analysis of Late Woodland projectile points in the upper Ohio River Valley and in west-central Illinois reveal that the points exhibit a gradual size reduction during 2000 to 1000 BP.

Essentially, “several points types defined for the American Bottom region effectively partition a continuum of metric variation” (Shott 1996: 288). He contends that existing point styles were simply reduced in size to accommodate the bow and that this is the result of a gradual transition from the dart to the arrow and not an abrupt one as is presumed in most areas of the U.S.. While this is at odds with the findings from most regions, Sollberger (1970: 152) indicates the predominant dart point types found in differing geographical areas at the time of the introduction of the bow in Texas became the prototypes for arrows. In central Texas, the Edwards point “developed from associated dart point prototypes found in the Edwards Plateau Aspect”; in east Texas, “ there is a good probability that the Alba derived from dart points like Ellis, Forney or Morrill.” The Scallorn derived from dart points like the Edgewood, Ensor of Fairland and the contracting stem styles such as the Bonham and Perdiz possibly derived from the Gary. In a similar vein, research from central Texas (Fawcett 1978; Fawcett and Kornfield 1980) seems to indicate a continuous reduction of neck width through time although their sample size was admittedly small. Some contend a gradual transition to the bow implies indigenous development as opposed to the diffusion of a new technology (Nassaney and Pyle 1999).

Similarly, Patterson (1994) and Odell (1988) indicate that bow and arrow usage extends back into the Archaic period as evidenced by unifacial arrow points consisting of slightly modified flakes. This implies that the bow would have been an indigenous development and not the result of diffusion from the north. It is difficult to conceive of why the prehistoric users would have been relegated to such a crude projectile point after thousands of years of bifacial reduction. Though there certainly are examples in the Old World of unmodified or slightly modified flakes, these appear to be isolated occurrences in the U.S. and whether or not they are arrow points is a matter of contention.

Overall, there is little clear evidence to support the claims of indigenous development of the bow in Texas, or other areas of North America. Issues for the timing of the introduction of the bow notwithstanding, numerous studies have demonstrated the relevance of neck width as a chronological device (Corliss 1972: Fawcett 1978; Fawcett and Kornfield 1980; Hughes 1999; Nassaney and Pyle 1999) and it appears that in most areas it can discriminate between dart and arrow points. That is certainly the case with the projectiles used in this thesis project.

CHAPTER 3

DISCRIMINATION OF DART AND ARROW POINTS IN NORTH CENTRAL TEXAS

The sample used to substantiate that there was a transition from the dart to the arrow consists of 575 bifaces presumed to be projectile points obtained from excavations at 12 sites, containing 28 components (Table 2). These were recovered in mitigation efforts related to the construction of Ray Roberts Lake and Lewisville Lake (Ferring and Yates 1997, 1998). The sites range in time from the Middle Archaic (7500-3500 BP) to the Late Prehistoric (1250-250 BP) periods. While there is only one Middle Archaic component, there are 13 Late Archaic components and 14 Late Prehistoric components. The overall goal in this section is to substantiate that there was indeed a transition from the atlatl to the bow and arrow. However, emphasis will also be placed on the parameters that define or separate dart and arrow points in the Upper Trinity River during the Late Holocene.

The dart points are represented by several varieties of stems including: contracting, rounded, rectangular, expanding and corner notched. These consist of 13 formal types some of which are: Gary, Godley, Ellis, and Kent (Table 2) (Turner and Hester 1993). The Gary point predominates the assemblage (*n*=79) followed by Godley (*n*=35) and Ellis (*n*=13). There are also a number of indeterminate forms.

Table 2. Dart point frequency by type and site. Note the high frequency of Gary and Godley. (Edge = Edgewood).

Site	Gary	Godley	Elam	Ellis	Dallas	Ensor	Edge	Darl	Kent	Hayes	Morrill	Marcos	Yarborough	Colbert	Langtry	Totals
41DN26	9	3														12
41DN 27	14	9		2	1	2	1									29
41DN 372	6	3	3													12
41DN 381	6	8	4	1	2		3	3	2	1	1	1	2			34
41CO 150	7	3		3		3		1				1	1			19
41CO 144	3	3		1												7
41CO 141	5			1												6
41DN 197	7						2									9
41DN 99	7	2		2			3		2				1			17
41DN 346	9	2	1	2									4	2	1	21
41DN 102	6	2		1					2				2	1	1	15
Totals	79	35	8	13	3	5	9	4	6	1	1	2	10	3	2	181

Arrow types include: Scallorn, Bonham, Alba, Washita, Toyah, Catahoula, Perdiz and Harrell (Turner and Hester 1993). The Bonham and Alba points often graded into one another and were thus catalogued as a single type. These were also the most numerous (*n*=124) followed by Scallorn (*n*=52) and Catahoula (*n*=35). As with the dart points, there are a number of indeterminate forms, totaling 126 between the two groups.

Table 3. Arrow point frequency by type and site. Note the high frequency of Alba/Bonham.

Site	Alba/Bon	Scallorn	Washita	Catahoula	Perdiz	Harrell	Washita-Toyah	Toyah	Friley	Total	Indeterminate
41DN26	22	6	1	8	1			1	1	40	21
41DN 27	18	4	11	6	9		1			49	21
41DN 372	34	10	6	5	1	2				58	31
41DN 381	22	2	2	4				1		32	18
41CO 150											7
41CO 144											4
41CO 141	7	8	2	4						21	4
41DN 197	3	2						1		7	2
41DN 99	4	4	2	5				3		18	7
41DN 346	5	11	3				1	1		21	5
41DN 102	9	5		3	5					22	6
Totals	124	52	29	35	16	2	2	7	1	268	126

Methods

For the analysis, only projectiles that retained an observable neck width area were used due to the assumption that this is the most discriminating attribute in determining whether a projectile is a dart point or an arrow point. This does not mean that the stem was necessarily still present. Some can have a missing stem and still have an observable neck width area at the base of the body of the point along the shoulders. Small triangular bifaces that are generally typed as Fresno were not included due the difficulty in determining whether these were actual points or preforms. As Sollberger (1970) indicates, preforms are not projectile point types. With these specimens there is also inherent difficulty in determining where to conduct the measurement for neck width.

In addition to neck width, the attributes of: neck thickness, length, maximum width and maximum blade length were measured with sliding digital calipers to the nearest 0.05 mm. Neck width measurements were taken in accordance Corliss's (1972) (Figure 3.1) method. Weight was calculated to the nearest 0.1 g. The attributes other than neck width and neck thickness were recorded for comparison to determine which was the most discriminating. Descriptive statistics and histograms were prepared for all of the attributes.

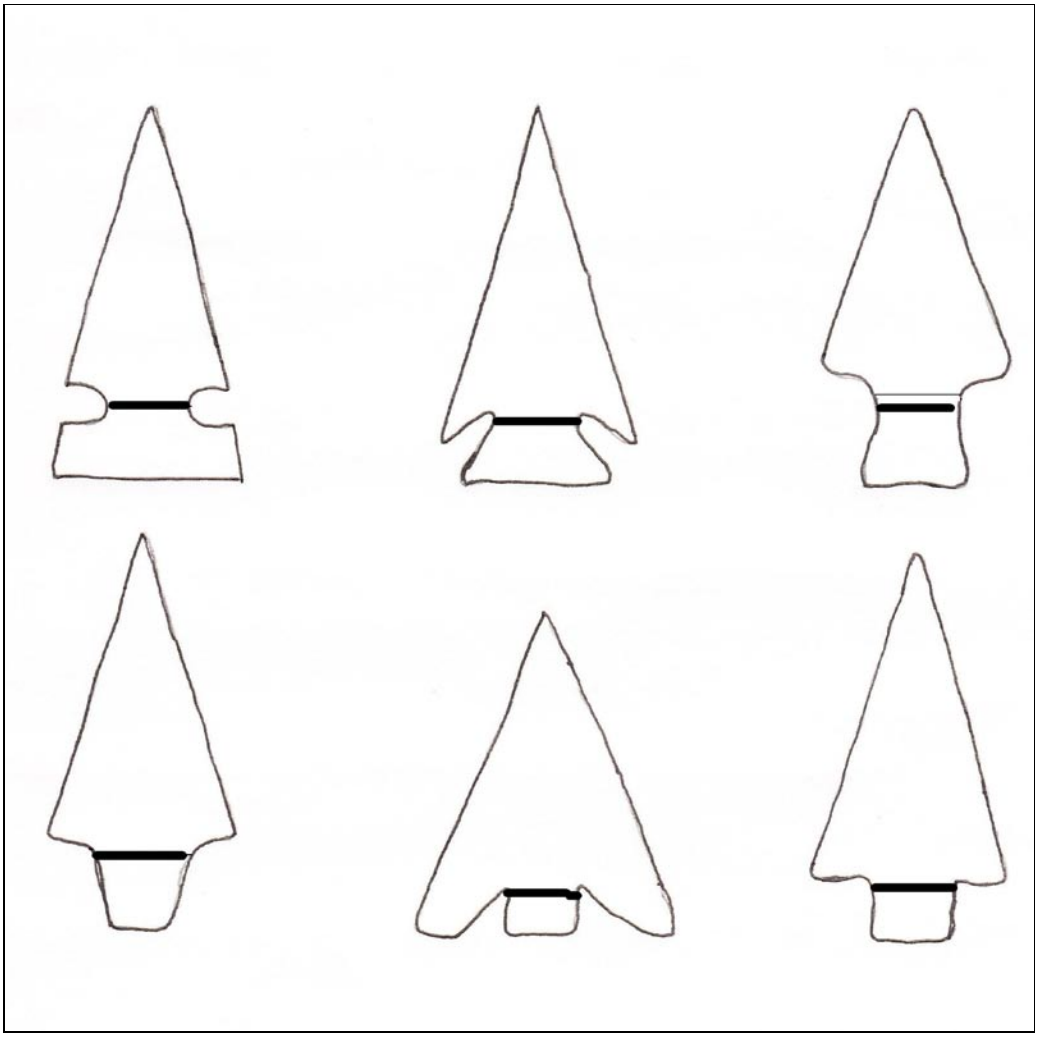


Figure 3.1. Neck widths of common forms of projectiles. Lines indicate area for location of measurement for neck width.

Analysis

None of the histograms exhibit normal distributions. Other than for maximum blade length, they all display a bimodal distribution suggesting that the sample represents two different size classes (Figures 3.2-3.7). Neck width appears to be the most discriminating attribute between the two size classes (Figure 3.2). This correlates with the diameter of the shaft to which it is hafted and it is assumed that the projectiles with the smaller necks will be arrow points and the larger neck widths will be associated with dart points (Corliss 1972; Forbis 1960; Thomas 1978). It is likely that the two peaks on the distribution represent different projectile systems as expected. As with some other areas, (Shott 1994, 1996) the neck width distribution data is continuous between the two groups. Although it appears the majority of the arrow points are < 8 mm neck width and the darts points are > 9 mm, 8-9 mm appears to be the transitional boundary between the two groups. But are these dart or arrow points? Nassaney and Pyle’s (1999: 250) study in central Arkansas, displayed discrete bimodal groups, which they used to classify dart and arrow points by their metric parameters. It is possible that distributions in that data set were a reflection of sample size (*n*= 93) because some of the sites used in this analysis such as DN102 (*n*=36), exhibit discrete distributions (Figure 3.7) when viewed at the site level. However, if the groups shown on the neck width histogram (Figure 3.2) could be separated the classes could be defined and statistical tests could be used to determine if there are indeed two groups of projectiles.

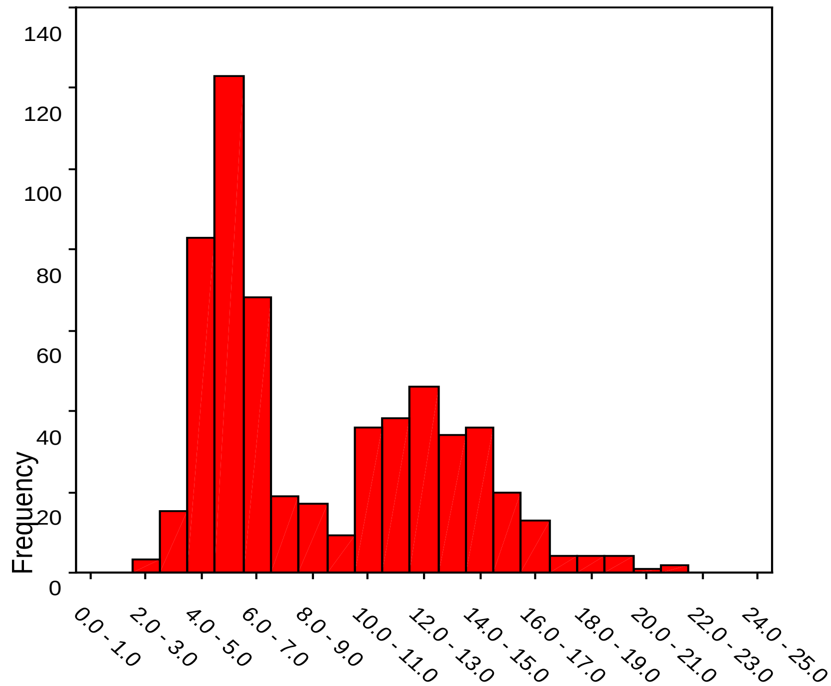


Figure 3.2 Projectile neck-width histogram. Note the bimodal distribution and the low frequency at 8-10 mm. (*N*=575)

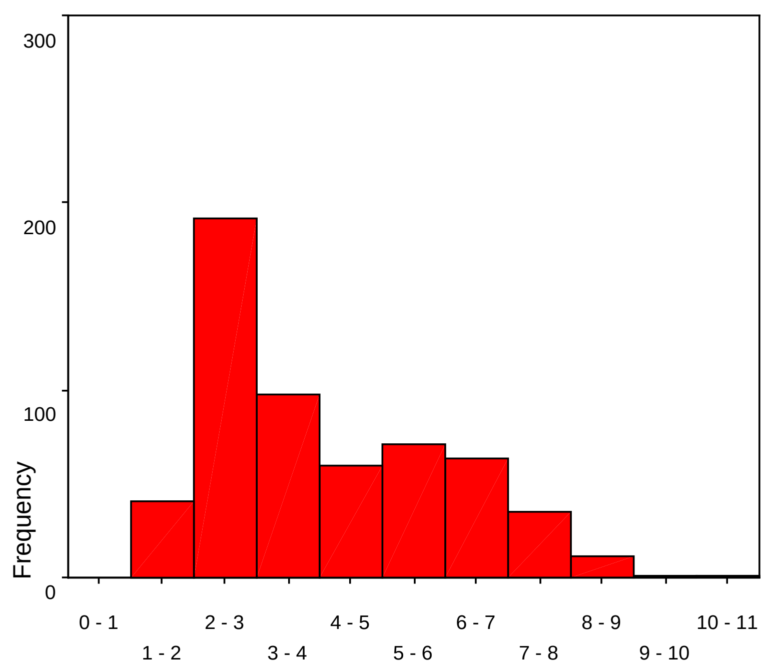


Figure 3.3 Projectile frequencies by neck-thickness (mm). Note the much more subtle bimodal distribution compared to that of neck widths. (*n*= 574)

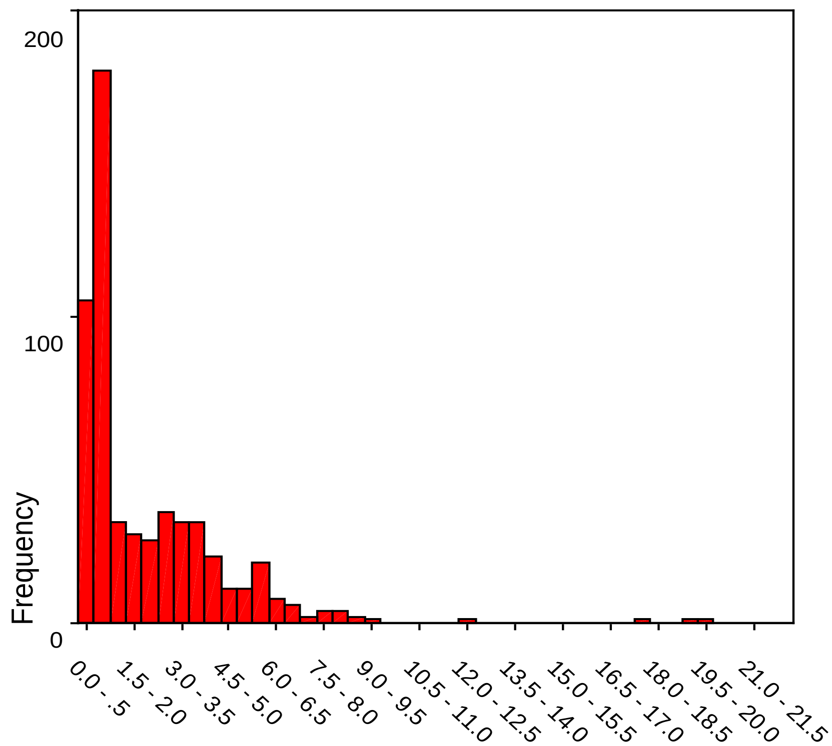


Figure 3.4 Projectile frequencies by weight (g). Note the polymodal distribution. (n= 571)

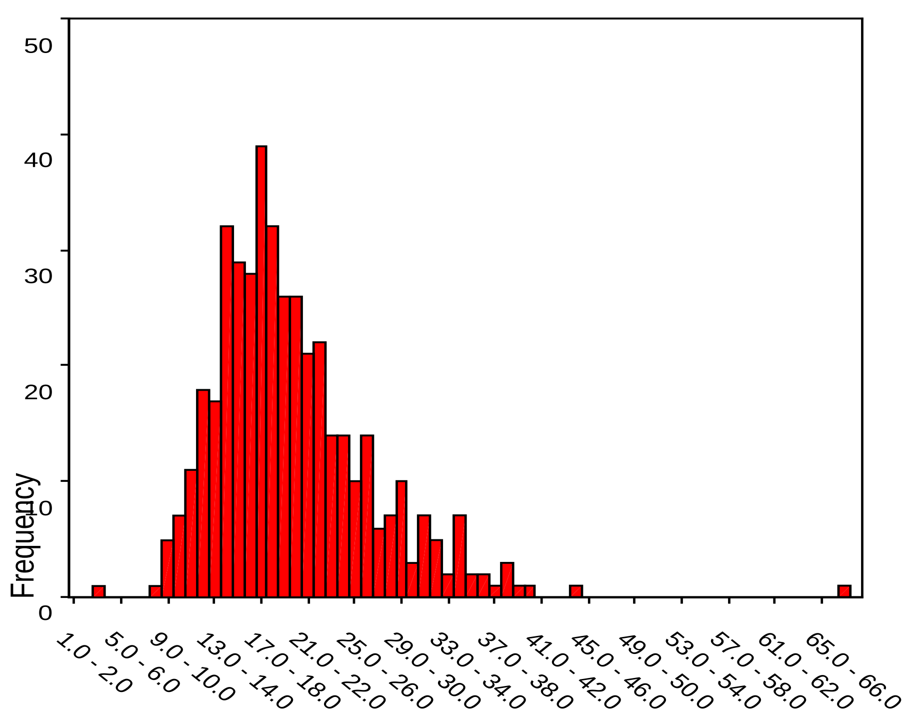


Figure 3.5 Projectile Frequencies by length (mm). Note the polymodal distribution. (n= 372)

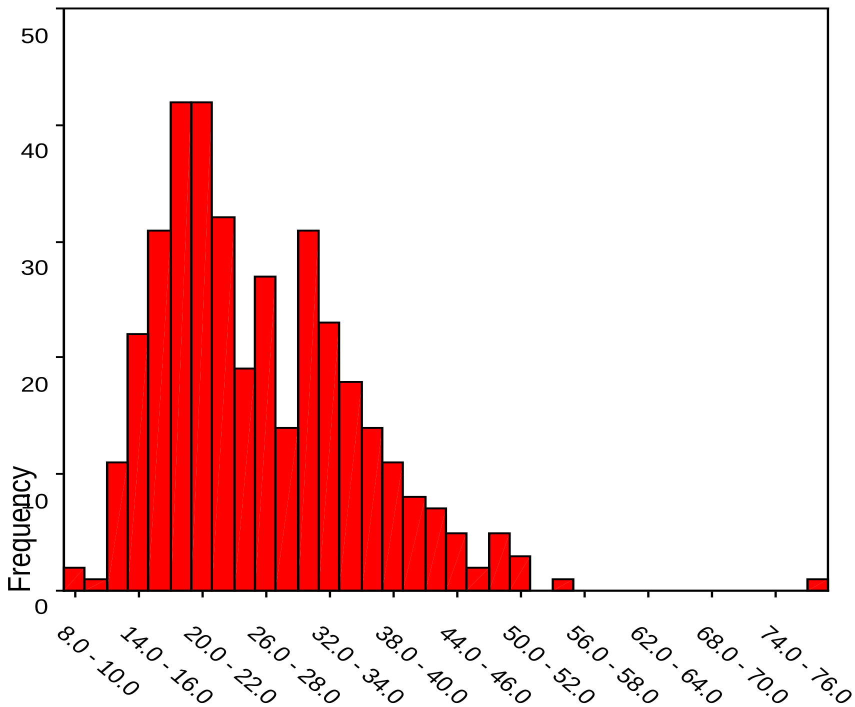


Figure 3.6 Projectile Frequency by maximum blade length (mm). Note the near unimodal distribution. This is likely a pleiotropic variable or "rider" on dependent variables such as neck width. (*n*=426).

It might seem logical to term the points in the 8-9 mm range as transitional however this term has a couple of connotations. First, it has a chronological implication in that these are at the transitional boundary between the Late Archaic and Late Prehistoric, which may or may not be the case. Second, it has a technological implication in that the points were part of a continual downsizing of darts points. As Sollberger (1970) suggests that some existing dart point types were prototypes for arrow types (See Abrupt or Gradual Transition). For these reasons the less subjective term, intermediate, will be used to describe the 26 specimens that are in the 8-9 mm range.

The intermediate specimens (*n*=26) account for only 4% of the 575 specimens in the assemblage and without these the size classes would be discrete. Thus, the specimens of this range were examined more closely in an attempt to separate the classes. Typologically there are differences between the 8mm group (*n*= 17) and the 9 mm group (*n*= 9) (Table 4). With the indeterminate forms excluded (*n*= 10), there are 2 dart points and 7 arrow points classified in the 8 mm group. While there are none classified as arrows in the 9 mm group. This suggests that the classes should be partitioned between 8 and 9 mm with arrows being < 8.99 mm neck width and darts being > 9 mm. The classes were thus divided.

Table 4. Frequency of 8-9 mm neck width intermediate projectiles by site. Note that there are no arrows on the 9 mm portion. Also note the clustering of points at DN27, DN372 and DN381.

				Projectile Points						
Site	Type			8 mm				8mm	Total	Total
	Scallorn	Bonham/Alba	Catahoula	Harrell	Gary	Godley	Indeterminate	Total	Darts	Arrows
41DN27	0	2	0	0	0	0	1	3	2	7
41DN372	0	2	0	1	1	1	1	6		
41DN381	0	0	1	0	0	0	3	4		
41DN103	0	0	0	0	0	0	1	1		
41DN346	1	0	0	0	0	0	1	0		
41CO150	0	0	0	0	0	0	1	1		
41CO141	0	0	0	0	0	0	1	1		
Total	1	4	1	1	1	1	8	17		

				Projectile Points						
Site				9mm				9mm	Total	Total
	Gary	Godley	Ellis	Edgewood	Ensor	Indeterminate		Total	Darts	Arrows
41DN27	0	1	0	0	0	1		2	6	0
41DN372	1	1	0	0	0	1		3		
41DN381	0	0	1	0	0	1		2		
41DN103	0	0	0	0	0	0		0		
41DN346	0	0	0	1	0	0		1		
41CO150	0	0	0	0	1	0		1		
41CO141	0	0	0	0	0	0		0		
Total	1	2	1	1	1	3		9		

With discrete groups, a Mann-Whitney *U* test was conducted comparing the mean neck-widths of the two groups. It revealed a significant difference between dart and arrow neck-widths. The mean neck-widths of arrows (*m* neck-width = 161.60) are significantly smaller than darts (*m* neck width = 448.87; U = 0.00, p < .05). Thus the expectation that the performance requirements of the spearthrower and bow place differing physical limitations on shaft size is reflected here with two size classes of projectile neck widths.

Further evidence for the assumption that there are two weapon systems represented in the projectile assemblage are the bimodal distributions of the other attributes of neck thickness, weight, length, and width. Neck thickness is also a reflection of the diameter of a projectiles shaft (Hamilton 1982) and this histogram (Figure 3.3) is bimodal although it does not appear as discriminating as neck width. This is likely due to the fact that thickness is harder to control for because it reflects blank-preform variability. Arrow point neck thickness is generally < 4 mm and the dart points are > 4 mm. The graphical distribution of weight indicates that the majority of arrow points < 1 gm and darts > 1 gm (Figure 3.4). The distribution of length shows that the majority of arrow points are < 26 mm with darts > 26 mm (Figure 3.5). However, in contrast, maximum blade length exhibits a unimodal distribution (Figure 3.6). This is likely a reflection of resharpening or reworking of the points and is possibly an indication that blade length is a pleiotropic variable or a “rider” on the other dependent variables such as neck width or thickness (cf. Hughes 1998). In sum, the bimodal distributions of all variables other than maximum blade length and the significant Mann Whitney test on mean neck width indicates that there are two classes of projectile points.

Definition of Dart and Arrow Points

Given the graphical evidence and the Mann Whitney test that indicates there is two distinct groups of projectiles it seems prudent to attempt to define those more closely. Nassaney and Pyle’s (1999: 250) study of the Plum Bayou culture of central Arkansas used discrete groups of data to define the metric parameters of dart and arrow points. Attributes such as neck-width and weight had breaks in the data that allowed the parameters to be defined. Possibly more important is the fact that those divisions held across attributes. The discrete classes of arrows and darts seen on the neck width distribution were the same as the discrete classes seen on the graphical weight distribution and so on. This is not the case with the assemblage employed from north central Texas. If the classes are defined using the 8-9 mm neck width procedure as above those will not be the same classes if split according to the intermediary data on the neck-thickness, weight, length and width distributions. There are several possible reasons for this.

1. It is possible that the divisions seen by Nassaney and Pyle are a reflection of sample size, theirs was *N*= 93 the sample here is *N*= 575. When data from the Upper Trinity is viewed at the site level there are some discrete distributions of attributes, as at DN102 (see Figure 3.7 below).
2. Some contend that the continuum is a reflection of a gradual size reduction from dart to arrow points as the bow was introduced. The existing types of dart points were simply downsized into arrows (Shott 1993, 1994; Sollberger 1970). This implies an in situ development of the bow as opposed to a diffusion of the technology or an episodic development of material culture.
3. Possibly these intermediate specimens are a result of resharpening or reworking of the dart points down to arrow point parameters.
4. It is possible that the specimens in the 8 mm range could be the result of the inherent difficulties in flaking the locally available Ogallala quartzite. 5 of the 7 typologically classified specimens are quartzite but there are numerous quartzite arrow points smaller than the 8 mm group (Table 3). And if this were commonly a factor there would likely not be spatial patterning to the frequency (see below).

5. As stated in Chapter 2, there can be overlap in the size of projectiles that will possibly function with the spearthrower and bow. Though not optimal they will function. Given the small percentage of points in the intermediary range (4% of 575) these may have been experimental. This view is supported by the fact that 76% of these (13 out of 17) are located at three sites at Lake Lewisville (Table 4), which suggests the forms were not random occurrences. One of these, 41DN372 was described by the excavators (Ferring and Yates 1998) as having transitional Late Archaic to Late Prehistoric remains and it contained 35% of the 8-9 mm specimens.

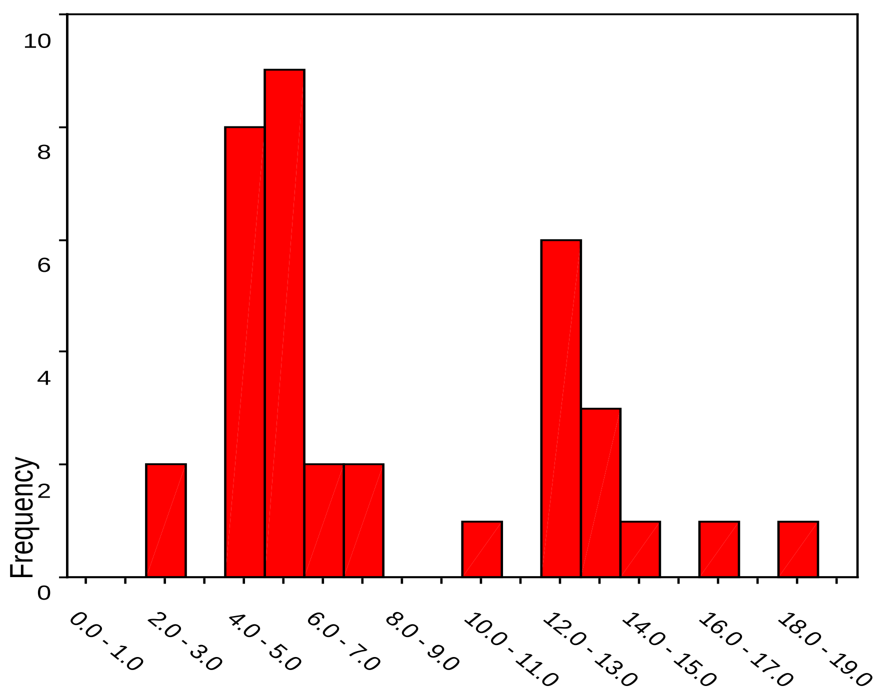


Figure 3.7. Projectile Frequencies by neck width (mm) from DN102. Note the discrete groups possibly due to sample size. (*N*= 36).

Ultimately the focus of this research is not on the few specimens that could have been used with either weapon but the ones that were generally employed or typified the projectile system. The mean of each attribute is most indicative of this parameter. Given that the most discriminating variable is neck width (Figure 3.2) and that there is a close correspondence between it and previously defined historical types (Turner and Hester 1993) it is likely that points with attributes located close to the mean functioned the most efficiently according to the users performance criteria. Essentially, only two points < 8.99 mm were classified as dart points and no arrows were classified > 9 mm. It is logical to partition the assemblage based on these criteria. When viewed from these groupings the mean of each attribute can be used to define dart and arrow points in north central Texas (Table 5).

Table 5. Classification of projectile points by metric parameters. Note the differences in mean neck-width between dart and arrow points.

	Dart		
Attribute	Parameter	Mean	*n*
Neck Width	> 8.0	13.1	253
Neck Thickness	> 2.38	5.8	253
Weight	> 1.4	4	249
Length	> 12.9	33.7	181
Width	> 6.9	19.4	240
	Arrow		
Attribute	Parameter	Mean	*n*
Neck Width	< 8.76	5.5	322
Neck Thickness	< 4.09	2.6	321
Weight	< 1.6	0.6	322
Length	< 33.5	19.6	191
Width	< 20.9	12.8	283

Table 4 is further indication that there are two groups of projectiles in the assemblage in that there are striking differences in the mean values. The mean neck width of darts is over twice as wide as arrows. Mean neck thickness of darts is slightly larger than the mean neck width of arrows. However, the most revealing may be the differences in mean weight, with darts being 4 g (n= 249) and arrows weighing only .6 g (n= 322). A Mann Whitney revealed a significant difference between dart and arrow point weights. The mean weights of arrow points (m neck width = 161.5) are significantly smaller than darts (m neck width = 446.94; U = 0.00, p < .05).

Discussion

In sum, the data presented here indicate that there are two size classes of hafted bifaces in the assemblage from north central Texas. Although these classes are not discrete they can be partitioned on the basis of overall morphology and size variation of attributes such as neck width, neck thickness, length, and weight. All of these variables show bimodal or polymodal distributions and a comparison of the means of neck width and weight reveal a significant difference between darts and arrow points. This difference is associated with the performance requirements of the spearthrower and the bow. Arrow shafts must have a thinner diameter shaft than dart shafts to enable them to flex around the handle of the bow.

Additional support for two classes is gained from the typological assessment of the projectiles in that the smaller group (< 8.99 mm) contains only two specimens that are defined as dart points while the larger group (> 9.0 mm) does not contain any specimens that are defined as arrow points. Thus the traditional typology for this area is sufficient for discriminating between dart and arrow points with a reasonable degree of accuracy.

There are 26 specimens located between 8-9 mm that can be seen as intermediate between the dart and arrow points on the neck width histogram (Figure 3.2). Functionally, points in this size range could have been used with either weapon system. As stated in the section on, Abrupt or Gradual Transition, there can be overlap in the projectiles that potentially work with the propulsive systems. This would not be optimal in terms of performance but it is possible. Alternately, these could be developmental forms associated with adoption of the bow (cf. Fawcett 1978; Fawcett and Kornfield 1980; Shott 1996, 1998; Sollberger 1970). They do not appear to be random because there is some spatial patterning to the frequency. 20 of the 26 were recovered from 3 sites at Lake Lewisville (DN27, DN372 and DN381). 9 of the 26 were recovered from DN372, a multicomponent site that is described by the excavators as possibly containing a transitional Late Archaic to Late Prehistoric component. It is not expected that these intermediate specimens would be related to reworking or resharpening because the hafted areas are not affected in those processes.

Claims of two weapon systems in the assemblage are supported by similar results from other regions that also show bimodal distributions of bifaces from the Late Archaic. Several studies indicate that the dividing line between dart and arrow point neck widths is around 10 mm (Fawcett 1978; Lynott 1975; Nassaney and Pyle 1999; Thomas 1978). The data here shows that it is slightly smaller at around 9 mm. Weight also segregates the classes as studies have shown that dart points > 4 g (Nassaney and Pyle 1999; Patterson 1985) as they are here. However, in this assemblage darts are > 1.6 g while the mean is 4 g. Essentially, although there is a clear division in this assemblage between the size classes of darts and arrows, they seem to be substantially smaller in relation to other regions. Unfortunately the mean size is rarely published from other studies for comparison. The smaller size in this area is possibly due to a scarcity of raw material as some have noted that it can constrain gross point size (Fawcett and Kornfield 1980: 74).

CHAPTER 4

LITHIC ANALYSIS OF THE UPPER TRINITY RIVER

Beyond the significant differences in the size of dart and arrow points there are fundamental differences in the life histories of the points and their associated tool kits. The investigation of these ontogenetic stages or operational sequences is known as the *chaine opertoire* (Sellet 1993) approach and is most commonly employed by European archaeologists (Knecht 1999). The stages include; raw material acquisition, construction, use (including storage, breakage and repair) and subsequent deposition in the archaeological record. Once these have been described and delineated, the choices and intent of the users is elucidated (Bradley 1975). Fracture mechanics of the stone remain the same, (cf. Cotterell and Kaminga 1987; Faulkner 1972) they are uniformitarian in the sense that the mechanical constraints that operated in the past continue to the present however, choices such as what raw material to use, the reduction strategy, patterns of use and discard are essentially what define cultural groups. The characteristics of these stages reveal information about mobility, subsistence/economic strategies, social life and the environment. The explication of these specific stages is not a straightforward task as they are generally saltational (Reid Ferring pers comm. 2006). In that with the exception of expedient forms such as unifaces, the tools and projectiles are not regularly manufactured, used, and discarded at the same locale. Thus rarely are all of the stages of the sequence represented at one site, which necessitates the inference of the missing portions. That will certainly be the case here.

This chapter is an investigation of the behavioral differences between Late Archaic people and Late Prehistoric people as they relate to the chaine opertoire of their lithic technology in the Upper Trinity River. These differences provide support for the claim of Chapter 3 that there are two distinct classes of projectiles in the assemblage. Additionally, the manufacturing and use trajectories of each indicate that there are fundamental differences in the procurement of the raw materials, reduction strategies, design construction and use of the projectiles. It is expected that the differences in the operational sequences employed during the Late Archaic and Late Prehistoric are associated with the production of dart and arrow points respectively. These were possibly the most crucial tools in that they supplied the bulk of the protein and lipid resources, at least from large game. They were the primary products and are the most numerous tools in the assemblages.

There are also associated tool forms such as thumbnail-scrapers, gouges and drills that are assumed to be part of the "tool kit", which were associated with each weapon system. Indeed, some archaeologists contend that the transition from the Late Archaic to the Late Prehistoric was not solely based on the adoption of the bow but on the adoption of a variety of traits such as bevelled knives, drills and pottery (Hughes 1989). Thus, this analysis will consider the importance of not only the projectiles but associated accoutrements as well.

Most applications of the chaine opertoire approach are based on a single site (Frison and Bradley 1980; Geneste and Maury 1997), however that will not be done in this analysis for several reasons. First, there are 12 sites and 26 components in this part of the project; to conduct a separate chaine opertoire for each one is simply outside the scope of the thesis in both space and time. Second, given that there are no known quarry sites in the area and the saltational nature of the life histories of the artifacts, no single site will contain the full range of the operational sequence. Third, although there are discrete LA assemblages, there are not any from the LP for comparison. This is due to bioturbation, surface stability, and geologic mixing. Essentially the traits that typify the chaine opertoire of each time period (or weapon system) will be illuminated and discussed and an overall operational sequence for the Late Archaic and the Late Prehistoric will be provided based on several sites. There is no evidence of sedentism or the intrusion of another culture(s); therefore it is assumed that these were temporary sites inhabited by the same cultural groups through time. As such, the sites are time-averaged representations of activities conducted as part of their subsistence round or circuit. The focus will be on how the sequences are different based on comparison, which further indicates the presence of two weapon systems and how this relates to the functionality of the tools and in turn the subsistence strategy. For instance, the overall morphology and contrasts in wear patterns on the projectiles implies that they were designed with different intentions. The analysis will be based on the published data from the original excavations (Ferring and Yates 1997, 1998) and will proceed in a chronological order of the operational sequences starting with the procurement of raw material. Assemblage summaries will be used to compare gross compositional variation among the components from the Late Archaic and Late Prehistoric.

It should be noted that the group of projectiles on Table 6, are not the same as those utilized in Chapter 3 on the Identification of the Weapon Systems. These are associated with the original excavations (Ferring and Yates 1997: 297, 1998) and are more inclusive as they include counts of all projectiles, including ones with only a portion of the neck or fragments, thus providing a more reasonable comparison to the counts of the other artifacts in the assemblage. Given the close corroboration between the neck width analysis and the traditional typology for the region (Turner and Hester 1993), it is assumed that the designations of dart or arrow in the published material are above reasonable accuracy for the lithic analysis.

Raw Material Procurement

The procurement of raw material is the beginning of the chaine opertoire and its selection has implications for the subsequent sequences. It is generally assumed that prehistoric people would seek the more homogeneous and isotropic varieties of siliceous stone that have the least directional dependent properties (Cotterell and Kaminga 1987). This allowed for more predictability in the manufacture of the tools. Additionally, certain types of stone were more appropriate for certain types of tools. Heavy-duty tasks such as chopping were often conducted on more resilient lithics such as quartzites, while the production of projectiles that required finer flaking and skill utilized finer grained cherts (cf. Banks 1990).

The assemblages from Lake Ray Roberts and Lake Lewisville contain ortho- and meta-quartzites as well as petrified wood (Banks 1990) however; they are dominated by locally obtained Ogallala quartzite. This is a derived metaquartzite that is procured from high strath terraces and upland surfaces (Menger and Slaughter 1968) and was the most commonly available stone in the Eastern Cross Timbers.

The cherts in the assemblage are almost all “regional cherts” in that there is no specific source that has been identified (Ferring and Yates 1997). Minor fractions include Edwards chert, Markley conglomerate and Chico Ridge chert although it is likely that the most abundant source are Uvalde gravels. These are lag deposits on Tertiary and Pleistocene terraces as well on upland interfluves. Byrd (1971: 5) indicates that the composition ranges from pebbles to boulders of chert, quartz, jasper, quartzite, limestone, and silicified wood, all of which are represented in the projectile assemblage. Banks (1990: 190) states that the Cross Timbers contains Uvalde gravel veneers while the Blackland Prairie and Grand Prairie are “chert free regions”. Thus, prehistoric people were forced to use lithic materials from surrounding regions, which conditioned transport and curation patterns seen in the Ray Roberts and Lewisville assemblages. Ogallala quartzite would have been available along the Upper Trinity in the Cross Timbers but procurement of sizable cherts were likely embedded in hunting forays to the west or possibly through exchange.

Debitage

With the exception of one stratum at 41CO150A that contained a single cluster of ca. 800 chert flakes and resulted in a frequency of 79%, the frequency of chert use among all assemblages varies between 8-32% (Table 7). With this outlier removed, the mean-chert frequency for the Late Archaic debitage samples is 18%, as are the Late Prehistoric samples. Overall, this would indicate that there was little difference between the amounts of chert that were used however; in general the Late Archaic samples with high chert frequency statistically correlate with high small-large flake ratios. The small chert flakes are 15% and the large flakes are 7% suggesting that this was the result of tool maintenance because large early stage flakes are underrepresented. In contrast, the Late Prehistoric small-large flake chert ratios are equal at 9% suggesting a different strategy of use. It is worth noting that the production of arrow points is possibly underrepresented due to the small size of the debitage. With the mean weight of the arrow points being .6 g (*n*=322) the initial blanks may have been so small that a large portion of the flakes would likely require mesh screen for recovery.

Table 6. Debitage size and chert frequency. The Late Archaic total is 18% with the debitage from CO150A taken out as an outlier. It contained a single cluster of ca. 800 chert flakes and chips (Ferring and Yates 1997). Thus both the LA and LP are equal with 18% chert. The ratio of lg/sm chert suggests increased maintenance of tools in the LA.

Late Prehistoric	LG QTZ	SM QTZ	LG CHT	SM CHT	PCT CHERT
Mean	0.44	0.37	0.09	0.09	0.18
LATE ARCHAIC	LG QTZ	SM QTZ	LG CHT	SM CHT	PCT CHERT
Mean	0.4	0.38	0.07	0.15	0.22

Cores

Cores especially those from chert, are not common in the Late Archaic (LA), although at 41DN99, 42.9% of the cores are chert (Table 7, Graph 4.1 A). This is also the only site with any chert blank-preforms. At 41DN372, and 41DN381, 11% of the cores were chert. Frequencies of quartzite cobbles are quite low given the supposed proximity of the source. They average only 3% of the gross assemblage composition and range from 2-14% (Table 8). Only five of the 13 assemblages contained cores. It is likely that due to a paucity of lithic resources Late Prehistoric (LP) groups scavenged cores from LA sites. The highest core frequencies are at sites with rapid burial (Ferring and Yates 1997).

Table 7. Chert frequency among tools. Note the discrepancies in blank-preforms relative percentages between the Late Archaic and Late Prehistoric (adapted from Ferring and Yates 1997).

Loc	Late Prehistoric	Cores	Bl-Preforms	Bif Frag	Unifac	Arrow Points	Dart Points
RR	DN102/1/1-4	33.3	17.6	41.6	55.5	34.5	46.1
RR	DN99/1/2-7		4.7	38.4		58.6	29.6
RR	DN197/22-24		100	50		50	
RR	DN346/1-6			45.5	66.7	40	30.9
RR	CO141/1/4-7					66.7	
RR	CO141/2/3-4				100	20	
RR	CO141/2/5-7		12.5		100	11.1	25
RR	DN103/2-5		50			31.3	16.7
LL	DN26/3-9	40	13	53.8	54	43	27
LL	DN27/3-10	20	20	28.8	53	41	12
LL	DN372/1-5		22	55.4	74	46	
LL	DN381/10-15		50		75	50	25
LL	DN381/16-22	33	17	48	74	46	
	AVG.	10	24	29	50	41	16
Loc	Late Archaic						
RR	CO144/1/3-7						25
RR	CO144/2/2-6				66.7		100
RR	CO144/1/9-13						
RR	CO141/1/8						50
RR	DN103/6-7						50
RR	DN99/1/8-15	42.9	8.3	50	60		37.5
RR	DN346/7-12				100	50	40
RR	DN102/1/6-9				100		50
RR	CO150/2/A			100	100		76.9
RR	CO150/2/B			75	66.7	25	16
RR	CO150/1				66.7	62.5	8
LL	DN372/6-9	11	13	37	57	50	28
LL	DN381/23-30	11	11	38.4	78		69
	AVG.	5	2.5	23	53.5	14	42

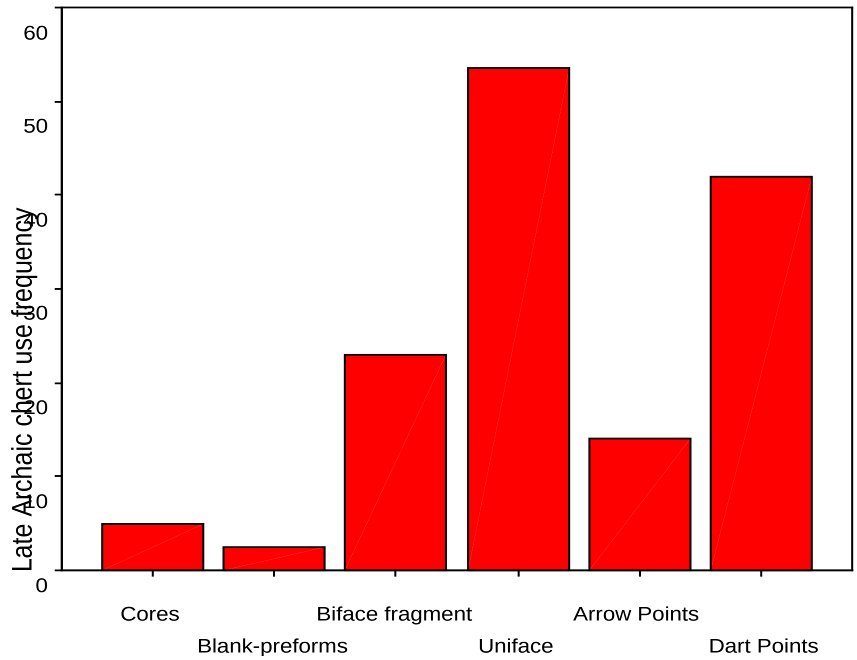


Figure 4.1 A**.** Late Archaic chert frequencies among tools. Note the discrepancies in blank-preforms relative percentages between the Late Archaic and Late Prehistoric (data from Ferring and Yates 1997).

In the LP assemblages, four sites have chert cores. The highest frequency is 40% at 41DN26 and the lowest is 20% at 41DN27 (Table 7, Graph 4.1 B). Quartzite is more common with 10 of the 13 assemblages containing cores (Table 8). The highest frequency of cores relative to the gross assemblage is only 6% at 41DN141. Thus twice as many sites in the LP group have cores although the average for the both the LA and LP is 3%. The overall scarcity of cores in both the LA and LP assemblages suggests that a significant portion of the earliest operational sequences were conducted elsewhere, especially for chert tools.

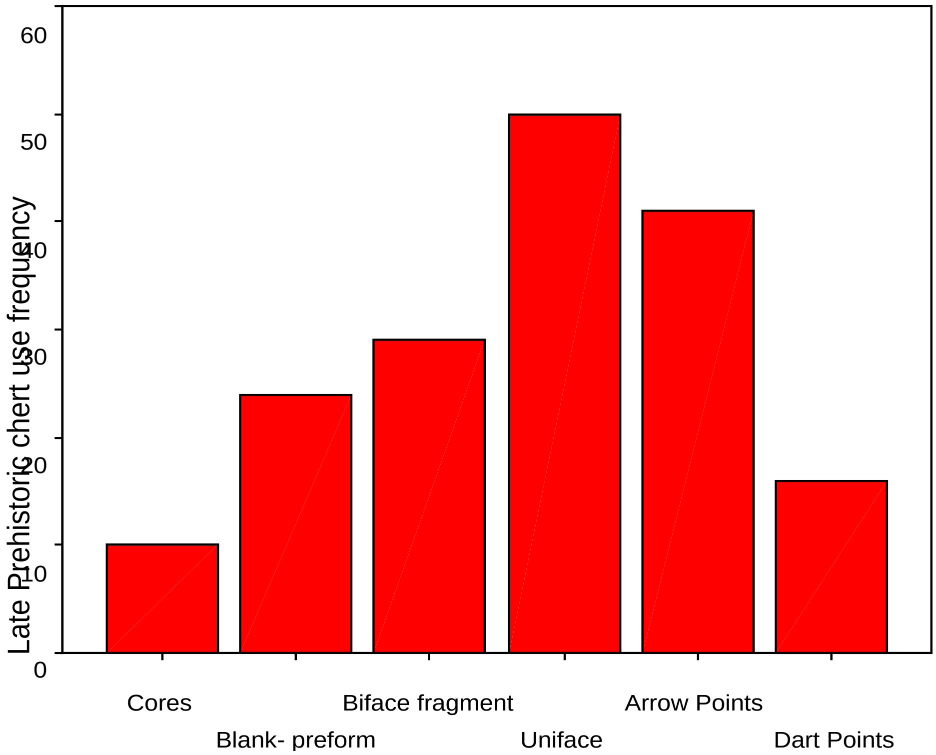


Figure 4.1 B**.** Late Prehistoric **c**hert frequencies among tools. Note the discrepancies in blank-preforms relative percentages between the Late Archaic and Late Prehistoric (data from Ferring and Yates 1997).

Table 8. Gross assemblage summaries. Note that the time periods are equal in core frequency, the higher frequency of blank-preforms in the Late Archaic and the increase in bifacial fragments in the Late Prehistoric. (adapted from Ferring and Yates 1997).

	Late Prehistoric							
			Bl-Preforms	Bif Frag	Unifaces	Arrow Points	Dart Points	N
RR	102/1/1-4	0.03	0.2	0.12	0.09	0.29	0.26	99
RR	99/1/2-7	0.04	0.22	0.13	0.03	0.3	0.28	97
RR	197/22-24	0	0.14	0.29	0	0.57	0	7
RR	346/1-6	0.04	0.19	0.1	0.03	0.27	0.37	113
RR	141/1/4-7	0	0.1	0.1	0.2	0.6	0	10
RR	141/2/3-4	0	0.25	0	0.33	0.42	0	12
RR	141/2/5-7	0.06	0.13	0.06	0.06	0.5	0.19	32
RR	103/2-5	0.04	0.32	0.08	0.04	0.16	0.16	25
RR	26/3-9	0.03	0.08	0.09	0.24	0.23	0.33	305
RR	27/3-10	0.04	0.16	0.15	0.23	0.11	0.3	371
RR	372/1-5	0.03	0.09	0.16	0.15	0.48	0.1	237
LL	381/10-15	0.03	0.17	0.1	0.14	0.11	0.43	28
LL	381/16-22	0.04	0.07	0.19	0.2	0.33	0.15	161
	AVG.	0.03	0.16	0.12	0.13	0.34	0.2	
	Late Archaic							
RR	144/1/3-7	0	0.17	0	0.17	0	0.67	12
RR	144/2/2-6	0	0	0	0.75	0	0.25	4
RR	144/1/9-13	0	0.75	0	0.25	0	0	4
RR	141/1/8	0	0	0	0.33	0	0.67	3
RR	103/6-7	0	0.33	0	0	0	0.67	9
RR	99/1/8-15	0.14	0.24	0.04	0.1	0	0.48	50
RR	346/7-12	0.02	0.39	0.04	0.07	0.04	0.43	46
RR	102/1/6-9	0	0.17	0	0.17	0	0.67	6
RR	150/2/A	0.08	0.04	0.08	0.25	0	0.54	24
RR	150/2/B	0	0.26	0.11	0.17	0	0.46	35
RR	150/1	0	0.12	0.06	0.35	0	0.47	17
LL	372/6-9	0.06	0.11	0.23	0.11	0.35	0.14	144
LL	381/23-30	0.05	0.15	0.22	0.15	0	0.42	59
	AVG.	0.03	0.21	0.06	0.22	0.03	0.45	

Blank-Preforms

There are marked differences between LA and LP in terms of blank-preform usage. Although they account for a higher percentage of the total assemblage in the LA at 21% compared to 16% (Table 8), the majority of these are local quartzite. Chert was used much more frequently in the LP than in the LA (24% to 2.5%) (Table 7, Graph 4.1 A, B). The general lack of chert cores in the LP assemblages combined with the high frequency of blank-preforms suggests that the latter were curated and imported to the site. The LA assemblages indicate a different pattern although blank-preforms account for more of the gross assemblage only 2.5% are chert.

Unifacial and Bifacial Tools

In the LA assemblages chert use is quite high for unifacial and bifacial tools in comparison to blank-preforms, from 53% and 23% to 2.5% (Table 7, Graph 4.1 A). The use of chert for tools is substantially higher than would be expected from the chert debitage data (Tables 6-7). The overall lack of chert cores and blank-preforms combined with the high small-large chert debitage ratios support the conclusion that LA inhabitants transported curated chert tools and not cores or blanks-preforms (Ferring and Yates 1997). The fact that dart points are the most numerous tool and that 42% are chert also supports this contention. Late Prehistoric data on the frequency of chert use for unifacial and bifacial tools are similar to the LA; however, there is a substantial increase in its use for blank-preforms (Table 7, Graph 4.1 B).

Reduction Strategies

A detailed description of the reduction strategies would require an in-depth analysis of the debitage attributes and reduction stages or refitting which are outside the scope of this research although there are important aspects that can be gleaned from the published material.

Given that the dart and arrow points are the most numerous tools in the gross assemblages at 45% and 34% respectively, one could conclude that they were the primary products (Table 8). There is no doubt of their need, as they facilitated the procurement of the bulk of the protein and lipid (faunal) resources. Ethnographic studies indicate that stone points are used almost exclusively for large game (Ellis 1998). Given their frequency and overall importance it is likely that the points were the primary product of the reduction strategy and that other implements such as unifaces, scrapers, drills and gouges were secondary products.

Studies that have shown there are two trajectory models associated with the reduction strategies used to produce darts and arrows (Johnson 1989, 1993). One strategy involves initial percussion reduction and final pressure flaking (darts); the other utilizes flake blanks that are pressure flaked into arrow points. As Sollberger (1970: 151) notes, “Stone points come from two sources: cores or flakes.” And “The making of arrowheads from cores requires a great deal of *extra* work” (italics added). Projectiles the sizes of the arrowpoints (.6 mean weight) (Table 4) in this assemblage simply do not require initial percussion reduction other than to produce the flake-blank. Unifacial points are slightly modified from a flake-blank. The frequency of unifacial arrowpoints is 15%, compared to 1%, for darts (Table 9) supporting this assertion. Thus it is likely that the reduction strategy was constrained by the size of the final product and was fundamentally different from the earliest stages for the two projectiles systems.

Table 9. Relative frequencies of the morphological attributes of the projectiles. Note the high frequencies of beveling and reworking among darts and low percentage of unifacial specimens.

	Unifacial	Beveled	Reworked	N
Darts	1	44	62	253
Arrows	15	2	4	322

Late Archaic Reduction Strategies

There are two reduction strategies in the LA. One strategy used cores at the site in which all stages of reduction were conducted. In the other strategy, the earliest stages of reduction were conducted off site and thus are not represented. This will be termed a curated flake-blank strategy. In general, locally available Ogallala quartzite was reduced on site with a higher frequency than chert. The types of percussors used are not known, as they are heavily curated and virtually nonexistent in the assemblages. The initial choice in the reduction would be the size of the cobble (16-64 mm), boulder (>64 mm) or pebble (4-16 mm). It is likely that some local Ogallala quartzite cobbles would have allowed for multiple dart points, pebbles only one. If a cobble was selected for multiple points, decortication would ensue through percussion, and then a series of interior flake blanks would be detached (Figure 4.2). These would be bifacially reduced to rough preforms.

In the next stage the preforms are thinned and shaped into large bifaces through further percussion. Final shaping was done through a combination of percussion and pressure flaking. The debitage data (Table 5) reveal nearly equal amounts of large and small quartzite flakes at 40% and 38%. Three types of platforms were employed in the strategy: discoidal, single, and multiple (Table 10). The frequencies indicate that a multiple platform strategy was used 70% of the time. It was likely opportunistic, exploiting the natural morphology of the cobble. Secondary products such as gouges, scrapers, drills and unifacial tools could be produced from the debitage.

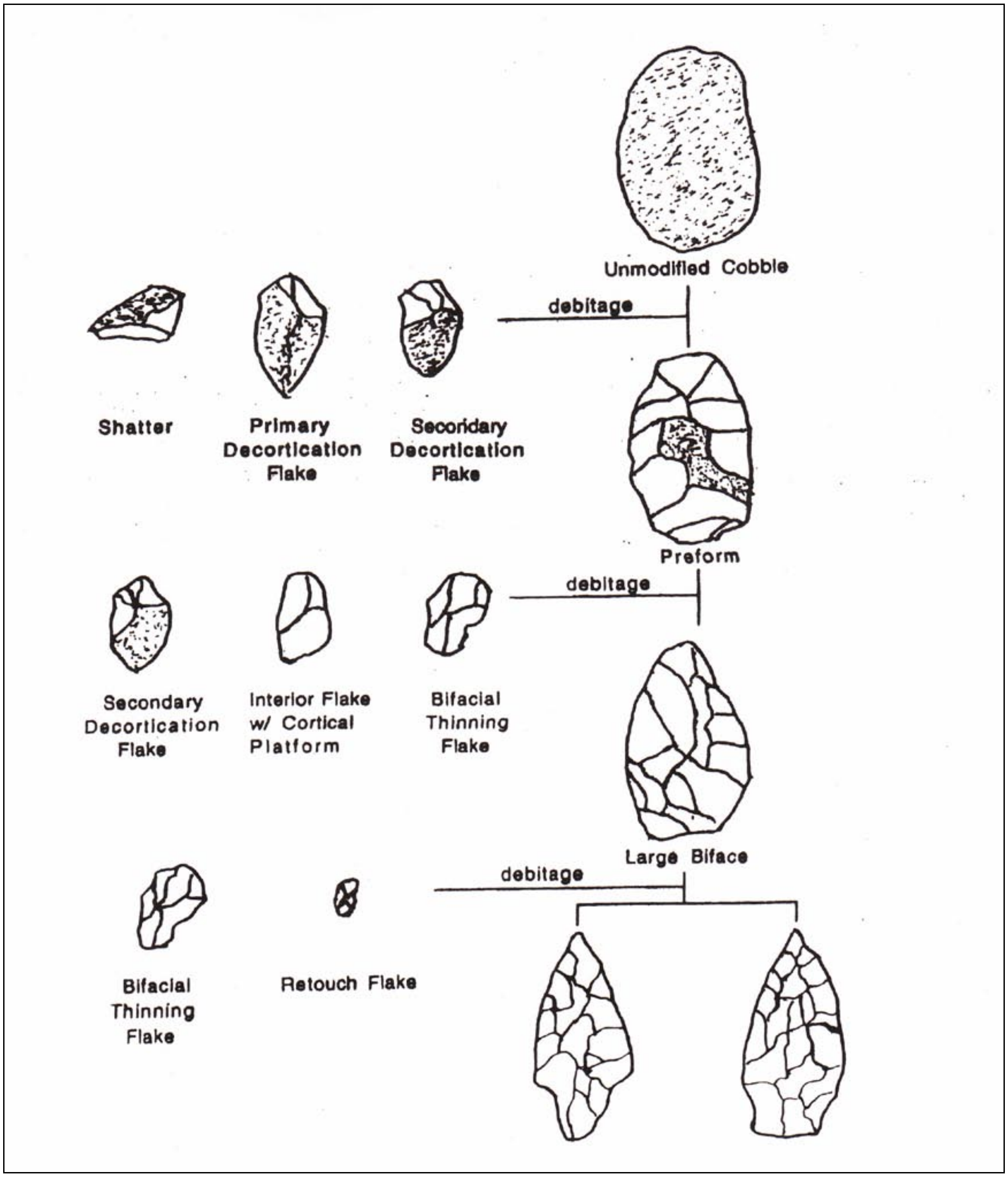


Figure 4.2. Late Archaic core-debitage reduction strategy. This strategy is characterized by initial bifacial reduction unlike arrow point manufacture (adapted from Nassaney and Pyle 1999: Figure 10).

Table 10. Core platform frequency summary. Note the increase in core platform types in the Late Prehistoric. Core fragments are not included in these counts. (chert/quartzite)

	Discoidal	Single	Multiple Platform	Opposed	Radial	Bipolar	Total
LP	-/2	1/20	3/14	-/7	-/1	4/-	8/44
LA	1/1	1/2	3/7				5/10

The operational sequence for chert core reduction would begin with procurement of resources off-site, likely to the west, although only five chert cores are represented in the assemblage (fragments excluded due to lack of platform) (Table 10). Due to mobility constraints among these foragers these were likely decortified and preformed at the source and reduced to final form in some cases. The same types of core platforms that were used for chert were also used for quartzite and in roughly the same proportions. Subsequent stages of reduction would proceed as above for the quartzite cobble.

Given the low frequency of LA chert cores (3 of 13 sites) (Table 7, Graph 4.1 A), the high percentage of small-large flake ratios (7% to 15%) and low chert debitage frequency (22%) (Table 6) it is difficult to account for the high percentage of chert tools. The fact that chert blank-preforms account for 2.5% of the assemblage indicates that the chert tools or their blanks transported to the site were likely already finished. The majority of the operational stages took place off-site as there are simply not enough chert cores and debitage to substantiate the frequency of tools and projectile points (Figure 4.3). Most of the chert reduction at the sites was for maintenance of tools. Provided the low frequency of Ogallala quartzite cores (5 of 10 sites)

(Table 8), this strategy was also applied to the locally available material. One note of caution in these interpretations is that the LA deposits, and more specifically the chert in those deposits, were likely scavenged to some degree by LP groups (Ferring and Yates 1998).

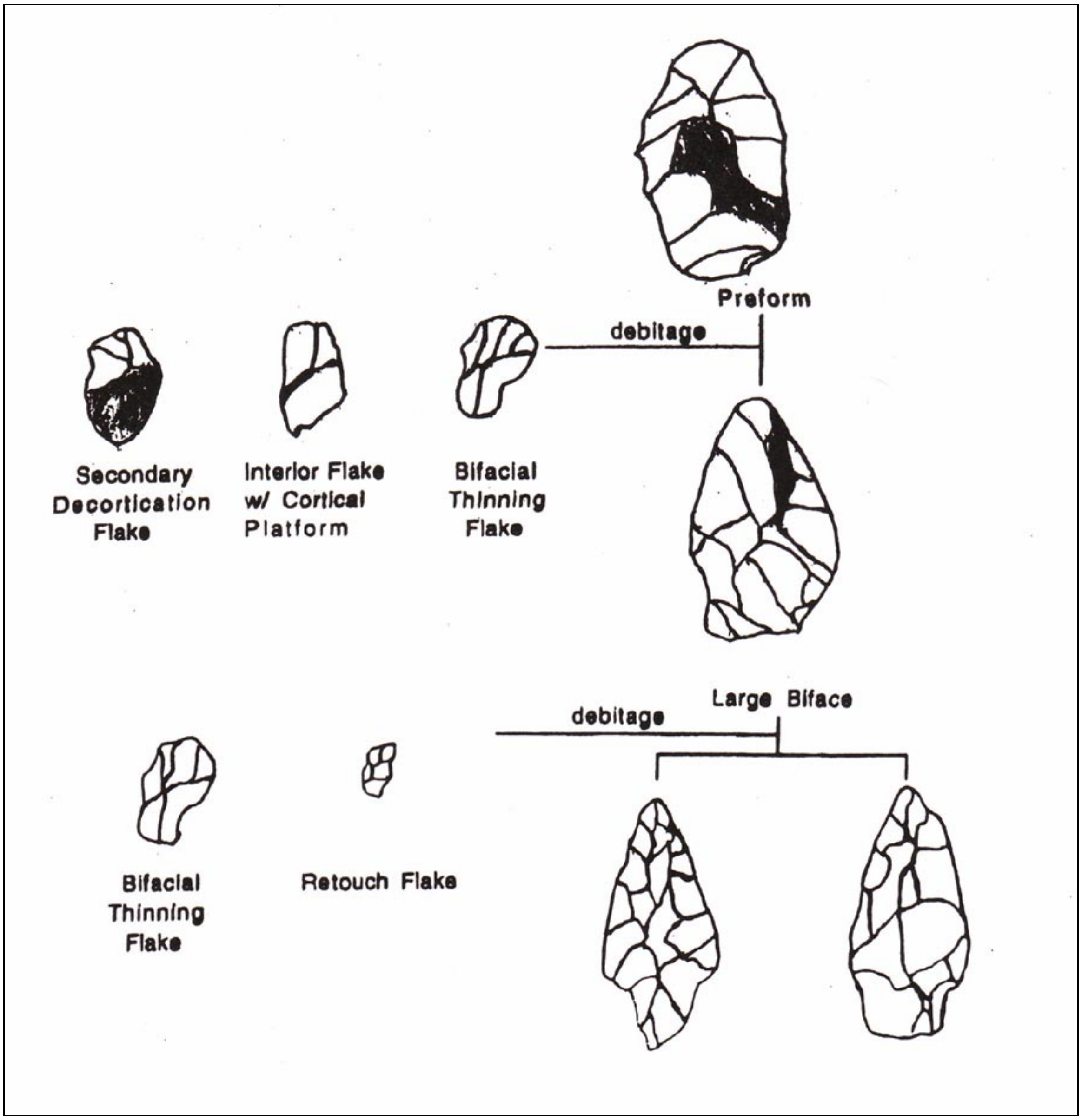


Figure 4.3. Late Archaic curated flank-blank reduction strategy. This diagram illustrates that some of the earliest stages are not represented at the sites in the Upper Trinity River, especially for chert (adapted from Nassaney and Pyle 1999).

Late Prehistoric Reduction Strategies

The fundamental difference between arrow point and dart point manufacture is that in the former, less percussion work is undertaken. After decortication, flakes would be detached and those of appropriate size and shape would be made into arrow points (Figure 4.4). Minor percussion work would be performed if needed, perhaps to remove the bulb of percussion, then marginal pressure flaking, bifacially or unifacially as required (15% of the arrow points are unifacial).

As with the LA sample there are differences in the operational sequences as they relate to the sites. Some products were fully reduced at the site others were not. In contrast to the LA there were more types of platforms employed (Table 10). In addition to those previously employed, opposed and radial were used for quartzite cores and bipolar platforms were the most frequently used on chert. Single platform is the most frequent on quartzite cores, followed by multiple. The debitage data shows more of a disparity in large to small quartzite flakes (44% to 37%) while chert is equal at 9% (Table 6). Although overall chert frequency is lower than in the LA, the increased large to small ratio contrast with the LA and suggests that earlier stages are more represented. These were likely from the reduction of blank-preforms as indicated by their high frequency and a low chert core count of only 4 (Table 7, Graph 4.1). The low chert core count combined with high blank-preform frequency indicates that chert was imported as blank-preforms and not finished tools as in the LA. This would be part of the curated flank-blank strategy in the LP (Figure 4.5). Due to the number of arrow points one could conclude that they were the primary product of the chaine opertoire; however, points this small could be produced from the debitage resulting from the production of the other tools in the assemblage as they are larger.

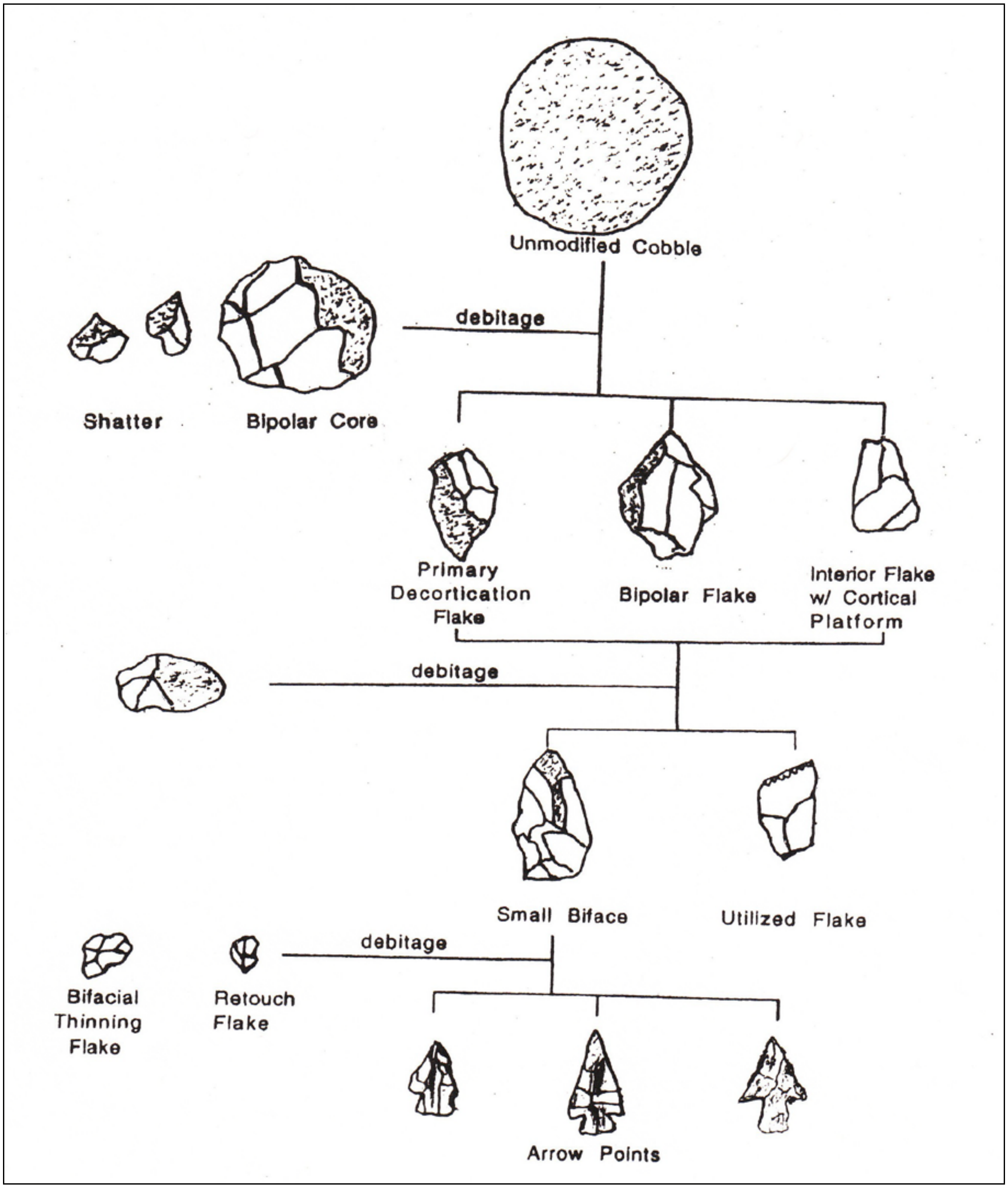


Figure 4.4. Late Prehistoric core-debitage reduction strategy. Note the lack of a bifacial preform as in Figure 4.1 (adapted from Nassaney and Pyle 1999).

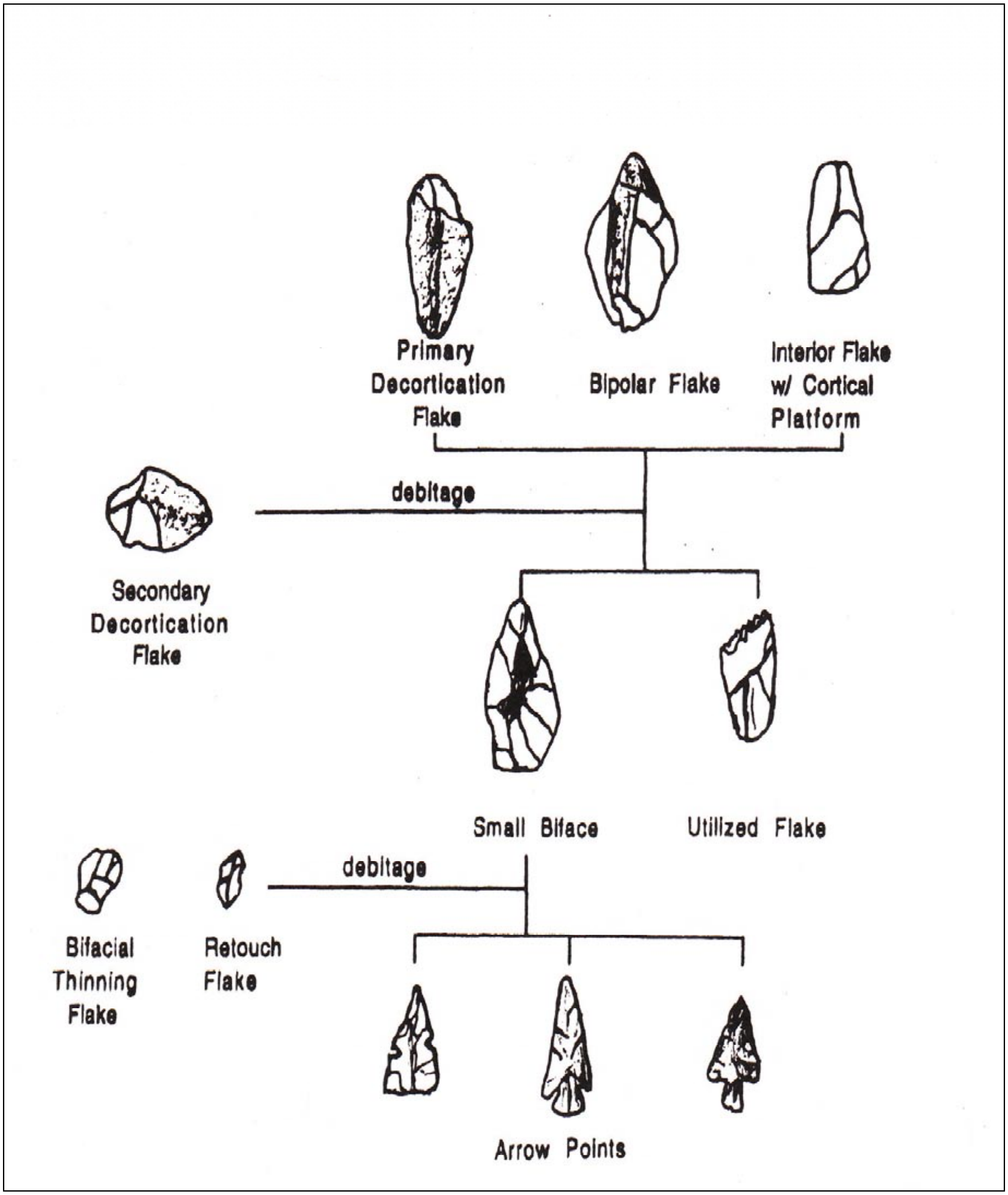


Figure 4.5 Late Prehistoric curated flank-blank reduction strategy. This diagram indicates that some of the earliest stages were conducted off site and are not represented in the assemblages (adapted from Nassaney and Pyle 1999).

Projectile Points

All indications are that the sites in the Upper Trinity were temporary hunting camps with some possibly approaching hamlet size (Ferring and Yates 1997, 1998). This view is supported by the projectiles predominance in the assemblages at the site level and the gross assemblage as well as generally large amounts of faunal remains. Although there are substantial differences in almost all aspects of dart and arrow point manufacture the frequency of chert usage for each is nearly identical (Table 6, Graph 4.1 A, B). Their numbers are also close as they relate to the percentage of the gross assemblage (Table 7). However, as with chert tools in the LA it is likely that the darts points were curated and imported to the site as finished products in a higher frequency than the arrows were in the LP. This claim is supported by several factors: 1) low number of cores, 2) low chert debitage, 3) high small-large flake ratios, and 4) blank-preforms account for 2.5% of the gross assemblage.

In contrast, LP assemblages have an increase in blank-preforms at 24.5% and in large-small flake ratios (Table 5). Although highly variable according to component, the abundance of chert cores is also higher in the LP (Table 7, Graph 4.1). Some of these differences may be due to scavenging of LA deposits by LA groups; however, at least in part they are related to mobility constraints. To transport cores and blanks large enough to accommodate dart points is more costly than to transport cores or blanks for arrows. Arrow point blanks are usually smaller than finished dart points. Thus, the location of manufacture for the projectiles was conditioned by the cost of transporting raw material. Dart points were generally constructed off-site and arrow points were constructed as needed.

Use, Maintenance and Discard

Two size classes of projectile points, the dart and arrow were identified in Chapter 3. The contrasts in size relate to the propulsive requirements of the spearthrower and bow. These weapons are indicative of the Late Archaic and Late Prehistoric periods respectively and this chapter has shown that there are differences in the reduction sequences used to manufacture the points as well as the associated tools in terms of raw material, transport and curation. This section demonstrates that there are also fundamental differences in the end sequences of the chaine opertoire: use, maintenance, and discard.

With the assumption that these are temporary hunting camps, there are a variety of processing and retooling activities that would have been conducted such as food preparation, hide processing, weapons maintenance and production, and woodworking. This would entail slicing, scraping, cutting, incising, and chopping. Some of these activities would have been performed with the bifacial and unifacial tools represented in Table 7, which indicates that unifacial tools were more frequent in the LA while bifacial tools were more frequent in the LP. Chert usage for these classes of tools is roughly similar. It is expected that the unifacial tools were manufactured expediently on site and discarded while the bifacial tools would have experienced portions of their life histories elsewhere.

The tools have not been subjected to use-wear analysis with magnification to determine their possible function(s). However, the projectiles bear macroscopic evidence of use and their design construction offers a wealth of information. It is assumed that the projectiles were employed for the same main function, which is the procurement of game, probably large game primarily (Ellis 1997). Beyond that there are contrasts in projectile maintenance/curation potentials that relate to size and or shaft design.

Shafts

The shaft of the dart and arrow can affect recycling potentials and multifunctionality. Although this chapter is concerned with the chaine opertoire of the lithics, the approach in this thesis has been on the weapon system as a whole, and a thorough understanding of the shafts is necessary to understand patterns of use, maintenance and discard of the projectiles. Thus a discussion of this parameter is in order.

Though there are no data on frequency, there is a common assumption in archaeology that a substantial number of darts used in prehistory were compound in construction with a detachable foreshaft (Hamilton 1982). This is based on the premise that it takes more time to create the haft (Keeley 1982) or the mainshaft than it takes to manufacture the point. Mainshafts 5 feet or longer are at a premium in certain geographical contexts and thus steps were taken to minimize damage to them. There are two known archaeological specimens from this region both of which are compound and likely detachable in construction (discussed in Atlatl Technology of the Study Area). One is from the Southern High Plains along the Cimarron River, Oklahoma (Baker and Kidder 1937) and the other was recovered Baylor Rockshelter (Fenenga and Wheat 1938) in the Trans Pecos of Texas. A compound shaft would have offered several advantages: 1) When the mainshaft detaches it does not have to withstand the rigors of an animal fleeing through brush; 2) As discussed in the Situational Comparison, the detachable foreshaft increases portability because a pouch full of foreshafts is substituted for a large number of cumbersome mainshafts; 3) Experimental studies indicate that selfdart (one piece) mainshafts may split upon impact at a higher rate than compound dart shafts (Cattelain 1997). In some cases, if a dart impacts a solid object such as a rock or bone the stone point can be driven backwards, splitting the shaft, thus destroying the costly mainshaft. A compound foreshaft mitigates against this problem. 4) A detachable foreshaft (more robust than an arrow) can facilitate resharpening, reworking (recycling) and multifunctionality.

Multifunctionality

The suggestion that some darts alternately functioned as knives or other tools has precedent in archaeology (Allchin 1933; Collins 1998; Ellis 1997; Ferring and Yates 1997, 1998; Goodyear 1974; Hester and Heizer 1973; Kay 1997; Nance 1971). Frison (1989) has noted that the Clovis point could have been used as a knife. They were designed such that the haft extends along the majority of the length of the projectile point, which guards against breakage by a combination of wood, ligature, and adhesive. Additionally, the Paleoindian period Dalton point has been considered a knife (Goodyear 1974, 1982) and Nassaney and Pyle (1999: 257) suggest that the Gary point could have functioned as a knife, especially the later forms that are chronologically associated with arrow points. They contend that there was contemporaneous usage of the bow and atlatl and that some of the darts were also employed as knives.

Two main factors allowed for the dart to be multifunctional: 1) Darts were not constrained by size or weight requirements of the bow and arrow; the dart point could be designed to withstand serial episodes of propulsion, resharpening, and or reworking. The mean weight of dart points in the assemblage is 4.0 g, compared to 0.6 g for arrows (Table 4). Projectile points the size of the arrows in this assemblage were likely not *designed* to sustain multiple episodes of propulsion and resharpening. Their degree of maintainability was not as great as the dart points. 2) The economization of the mainshaft through a detachable foreshaft provided a sufficiently stable handle that it could be used a knife or other tool (Goodyear 1974). In contrast, arrow shafts were too thin and fragile to sustain substantial sideward pressure (Ellis

1997). The neck width analysis indicates the average arrow shaft in the Upper Trinity River was around 5 mm; darts were around 13 mm (Table 4). It is expected that the dart points in this assemblage will exhibit greater evidence of maintenance than arrow points due in part to the robusticity of the shaft.

Analysis

During the process of measuring the various metric attributes for the analysis in Chapter 3, two other attributes were also recorded. *Reworking* is the first, and describes the modification of a broken or damaged point to produce a new, usable projectile point (Knecht 1997). Also included with this attribute is resharpening, which refers to the process of the maintenance of a damaged tip or blade of a point. Points that were severely damaged would be reworked while others were simply resharpened. Both could usually be accomplished with the projectile still in the haft. The criteria used to indicate maintenance in the form of reworking and resharpening are based more upon presence/absence than intensity and are as follows: 1) lateral retouch, 2) retouch over impact scars, 3) steps, 4) stacks, 5) shoulders wider than the body (from being resharpened in the haft), 5) stem longer the body (from resharpening), and 6) asymmetry. Steps and stacks could be a result of the manufacturing process; however, these were identified as having been the result of resharpening. The frequency of darts that were maintained through resharpening and reworking is 62% compared to 4% for arrows (Table 9) indicating that the latter were not commonly recycled (Figure 4.6).

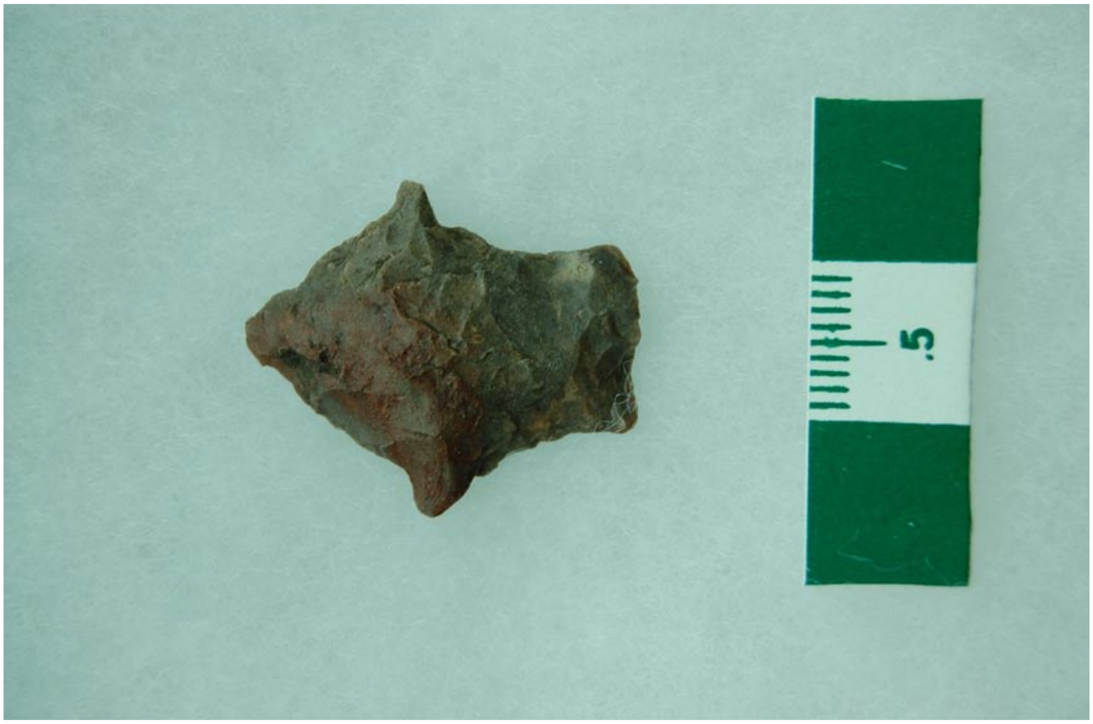


Figure 4.6. Reworked dart point from 41CO150. A prime example in that it has several characteristics such as the protruding ears, base longer than body, resharpening steps and it is slightly asymmetrical.

Beveling was the second attribute recorded that relates to maintenance. Some contend this implies multifunctional use as a knife because the edge angle is more conducive to slicing in butchery (Goodyear 1974; Sollberger 1971; contra Frison and Grey 1980). It is also more economical in that less material is lost in resharpening as compared to bifacial reduction (cf. Odell 1996). Sollberger (1971) indicates that the technique of microflaking entails that only small amounts of stone are removed to produce a sharp edge; whereas, bifacial resharpening quickly removes and concomitantly weakens lateral edges. Given the scarcity of quality lithic resources, particularly chert, in the Upper Trinity River area (cf. Banks 1990; Ferring and Yates 1997, 1998) it is expected that prehistoric people would have attempted to conserve material. There is no evidence that beveling was an advantageous design characteristic for a projectile; however, it could be a possible alternative in areas with scarce resources. Conversely, it is possible that beveling was the easiest method to resharpen a projectile that was still in the haft (Gene Stapleton pers. comm. 2008). While the reasons for beveling can be debated, be they for economization, multifunctional use, or both, the mere presence of beveling suggests recycling in the form of serial episodes of use. The data from north central Texas reveal that 44% of the darts are beveled compared to 2% of the arrows (Table 9) (Figure 4.7).

Figure 4.7. Beveled dart point specimen from 41CO150. Note beveled area.

These data show that, as with reworking, the majority of arrow points in this assemblage were not recycled after impact or as a result of becoming dull through use. It does not mean that they were not used as a projectile. If they did not strike a hard object such as a bone they could be have been reused. Neither the novaculite or chert points used by the author to dispatch a whitetail doe and buck respectively bear any visual evidence of impact and could have been rehafted and reused. The important distinction is that the darts in this assemblage were damaged in some manner, either through impact as a projectile or as a multifunctional tool, or both. Subsequently they were maintained through reworking, resharpening and in some cases beveling. It is possible that the points could have been beveled before they were damaged. Conversely, only a minor fraction of the arrow points exhibit signs of damage and maintenance. Thus, other than the fact that dart and arrow stone points were both employed for procuring large game, their life histories after manufacture were fundamentally different.

It is logical to ask, “Where are the cutting implements in the LP assemblages if the darts performed that task in the LA period.” This can partially be accommodated by a modest increase in biface fragments from the LA to the LP at 6% to 12%. Given the scarcity of lithics there is also the probability that as with the hammerstones these were highly curated. It is interesting to note that although the four-bevel knife was in common use to the east and south of the area as was the Harahey to the west (Krieger 1946; Sollberger 1971; Stephenson 1970) there does not seem to be a corollary to those forms in the Upper Trinity River during the LP.

Discussion of Design Construction

It is a rare occurrence in archaeology that an assemblage or culture will conform exactly to the characteristics stipulated by a theoretical model. For instance, there are few cultures that would fulfill all of the requirements for either group in Binford’s (1980) forager-collector continuum model of hunter-gatherer mobility. It illustrates a dichotomy between logistical and residential mobility. Collectors practicing logistical mobility establish multi-purpose base camps in ecotonal areas from which task groups exploit specific resources and bring them back to camp. Foragers practicing residential mobility travel as a group to resources at specific times, exploit the resources, and then move the whole group to a new location. Binford realizes that his sample is an exception in that the evident dichotomy is a result of significant seasonal variation in the Arctic and it is unlikely that most cultural groups will be under the same contingencies. Thus the model is somewhat over simplistic and does not account for the multi-faceted decisions that groups will encounter in variable environments; essentially, characteristics of hunter-gatherer groups often cross-cut our modern tendency to categorize them (Nelson 1991). Many hunter-gatherer groups share some traits of both ends of the continuum, possibly dependent on the time of year. Nonetheless the model has heuristic value in that it provides a framework for further discussion. A similar situation exists when the design of the dart and arrow are considered within established archaeological theory.

In a sense what has been discussed thus far in the thesis, as it pertains to the projectiles, are the factors that explain tool morphology. Why are dart points large, and arrows small? Why are 15% of the arrows unifacial but only 1% of the darts? Why are darts routinely reworked and beveled and arrows not? Essentially, what accounts for the disparities in the morphology of the projectiles? Design theory can be used in this endeavor and it postulates that these "are specific behavioral responses to problems encountered in a natural or cultural context" (Odell 1996: 8). It focuses on the constraints on tool design construction and morphology. These principles can "allow the hunting strategies and other behavior of prehistoric hunters to be inferred from the design of their hunting weapons" (Bleed 1986: 738). Some of the constraints that have been proposed include: adequate task performance, available materials and their relative costs, as well as relative use lives and repair costs (Hayden et. al. 1996: 11). A general dichotomy has been provided by Bleed (1986: 739) of reliable versus maintainable tool systems. Due to the fact that some characteristics are not operational for this assemblage only a few will be mentioned.

Reliable systems are characterized by overdesigned components (stronger than needed), carefully fitted parts and good craftsmanship, maintained and manufactured by a specialist, and a generalized repair kit. *Maintainable* systems are characterized by lightness and portability, a specialized repair kit that has ready-to-use extra components (difficult to determine archaeologically), simple design that can be repaired and maintained during use with a low level of lithic skill, and used in a range of functions.

Some researchers have noted, “reliable and maintainable systems may actually measure two different aspects of tools” (Hayden et. al. 1996) in that they can be neither or both (Torrence 1989; Nelson 1991). Just as it is difficult and imprecise to accommodate many hunter-gatherer systems to Binford’s (1981) forager-collector dichotomy, it is also difficult to apply the data and information from the Upper Trinity River dart and arrow assemblage to Bleed’s (1986) model, though it is also heuristically useful. The differences between the weapons systems crosscut the categories proposed by the reliable-maintainable dichotomy and others are archaeologically invisible. For instance, Nelson (1991) categorizes maintainable tools as those that are intended to be useful under task conditions that are primarily continuous but not predictable or where size and weight constraints are important. The corollary to this would be that size and weight are not important to reliable systems. Thus the dart and arrow do not seem to fit this dichotomy because size and weight were important to both systems. Nonetheless, design considerations are evident within the weapon systems of the atlatl and the bow and arrow. Although when they are compared directly, it is difficult to demonstrate that a design consideration is intentional or if prehistoric groups in the Upper Trinity river area were simply exploiting the characteristics that were inherent to the weapon systems. The fact that darts are reworked and beveled with substantially higher frequency could be a result of the allowable size of the dart and not necessarily because they were seeking a more maintainable projectile system in comparison to the arrow.

Design Considerations of the Upper Trinity River Projectiles

It is apparent that beyond use as projectiles for hunting large game, darts and arrows with stone tips were not employed in the same manner during prehistory along the Upper Trinity River. These potentials are a byproduct of size constraints imposed by the performance requirements of the weapon systems. The robusticity of the dart point with a detachable foreshaft offered more potential for sequential episodes of use and maintenance. They were *overdesigned* to allow for maintenance (Bleed 1986). Overall, the dart was a generalized strategy projectile system in that it was multifunctional. The empirical evidence of the disparities in reworking and beveling frequencies, as well as the theoretical use of the detachable foreshaft support this conclusion. The mainshaft was economized through the use of the detachable foreshaft and the foreshaft and stone point were curated in anticipation of future use (Binford 1979). Some researchers have noted wider variability in morphology of a tool category logically imply complexity of activity and a response by changing tool shape in order to adapt to varying needs (Bradley 1980). This analysis supports that conclusion.

Others contend that multiple functions of tools should characterize tools in which portability (due to mobility) is a constraint (Bleed 1986; Shott 1986) and the sites in the study area are considered temporary hunting camps (Ferring and Yates 1997, 1998). The low number of blank-preforms, low debitage counts and a high small/large debitage ratio suggests that the chert dart points were manufactured off site and maintained at the residential or logistical site during down time (Tables 6, 7, Graph 4.1 A, B).

Overall, the dart was a curated technology that primarily functioned as a projectile and secondarily was used for cutting, scraping and drilling. It was *versatile* (Nelson 1991; Shott 1986) in that it simultaneously could be used for different uses or *flexible* in that it was designed for sequential change in function (Nelson 1991). Others term this as *multifunctional* (Hayden et al. 1996).

The design considerations and construction of the arrows from the Upper Trinity were fundamentally different than the darts. The potential for arrows to be reworked was constrained by their diminutive size, the mean weight was only 0.6 g, whereas darts are > 1.4 g with a mean of 4 g. Though there is ethnographic evidence of the reuse of arrows (Holmberg 1950) and multifunctionality (Bleed and Hitchcock 1997; Greaves 1997) this is possibly related to the use of metal points in those contexts. Given the low frequency of reworking and beveling, there is little evidence in this assemblage of stone points to support that contention. Additionally, the shafts were likely from 4-8 mm in diameter, which would indicate that they could not support substantial sideward pressure. Thus, the evidence here suggests that the arrow points were designed for a single shot, if they did not strike a hard object they could be reused but they were not designed with that intention. The arrows were expendable in that as they were damaged they were replaced with a spare from the quiver. The shaft could be retrieved and retooled; however, the overall system was not designed with the intention of being salvaged. This relates to the lower relative cost of arrows compared to darts for which there are several reasons.

1. Relatively smaller stone arrow points being constructed from flake blanks and requiring little bifacial percussion would be less costly in terms of raw material, labor and time. The frequency of expediently produced unifacial arrow points is 15%, compared to 1% for darts supporting this claim.

2. Raw material, and likely, labor costs would be less with arrow shafts than darts. 76 cm (30 in.) shafts could have been more available than 152 cm to 182 cm (5 ft to 6 ft) dart shafts, which would increase resources. If a selfarrow were used, time and labor would not have to be expended on the foreshaft. Additionally, shorter shafts take less time to dry, scrape and straighten and they would reproduce faster than 152 cm to 182 cm shafts replenishing resources.
3. Portability costs are less with the arrow; 30 or 40 could easily be carried in a quiver (see Situational Comparison, Table I) increasing the projectile supply and mobility of the user. Ethnographic evidence indicates Ishi (Pope 1918) and "Oetzi" the iceman from the Tyrolean Alps (Spindler 1994) actually carried spare, *unfinished* arrows. Lee (1979: 135) states that "the quiver is a portable workshop" and that the !Kung San carry 10-15 finished arrows and a number of blank unfinished mainshafts. By contrast, Greaves (1997) notes that spears are cached at frequently used fishing sites to mitigate transportation.

The significance of a lower cost arrow was that it eased shot restrictions. The cost per shot was less with an attendant reduction in mobility restraints. Thus, game could be hunted and pursued more easily, possibly increasing success rates. Overall, the arrow technology was designed to be expendable, task specific (a single purpose) and sometimes expedient (unifacial points); the dart was designed to be maintainable and multifunctional. The dart's ontogeny was saltational in that it was used and recycled episodically leaving traces at various locales on the landscape, the arrow much less so. There is indication that it was produced off site and intended for several occurrences of propulsion, resharpening and reworking. Given the low frequency of reworking and beveling (4% and 1%) among arrows in contrast to darts (62% and 44%) in the

Upper Trinity region, one could possibly identify the weapon system with a reasonable degree of success by those parameters.

Summation

This investigation has detailed that beyond the stark differences in the size and use histories of dart and arrow projectile systems there are a variety of differences in raw material usage, debitage patterns, cores, blank-preforms, unifacial and bifacial tools, and reduction strategies. These are not entirely a result of the transition from the atlatl to the bow and arrow. They are associated with a variety of traits coincident with the Late Archaic and Late Prehistoric periods that are related to changes in settlement/mobility patterns, subsistence/economy and social patterns. This is not to discount the role of the weapons, it simply highlights that they are not the sole reason for the discrepancies in the lithic assemblages between the cultural periods.

The main similarity between the LA and LP assemblages is the raw material dichotomy between locally available Ogallala quartzite and imported chert. Quartzite dominates the assemblage in all tool categories other than unifaces and to a lesser extent the projectile points (Table 7, Graph 4.1). This suggests that higher quality and thus sharper lithics were reserved for tools that required a higher degree of cutting ability. LP groups continued the tradition of using local material for the majority of the on site manufacture of tools. The periods are also alike in that the few sites have chert cores, with four in the LP, and three in the LA. Further, the cores account for only 3% of the gross assemblage for both time periods (Table 8). This indicates that the majority of the early stages of reduction were conducted off site.

There are some substantial differences that relate to the cores. For instance, the sites are provisioned differently in that 5 of 13 LA sites contain cores while 10 of 13 LP sites contain cores. Though the number of cores relative to the other tools is low in the LP, substantially more sites contain them than in the LA. Low LA frequencies could partially be attributed to scavenging of lithic resources by LP groups and in a sense the sites were somewhat provisioned by earlier occupations in the LA. Exhausted dart cores and associated debitage could still have usable portions for arrow manufacture given the size differences. The transition to the arrow offered an increase in raw material. This is somewhat supported by the increase in the types of core platforms utilized in the LP with seven quartzite opposed cores, four bipolar chert cores and a radial core (Table 10). Usability of raw material is constrained by morphology and a smaller intended product can tolerate a wider degree of variation. Pebbles too small to produce blanks for darts can produce blanks for arrows by employing bipolar reduction.

Transport and curation strategies were clearly different between the periods. LA groups imported a higher frequency of finished chert tools as opposed to blank preforms or cores. Some of this was associated with the curated generalized projectile technology of the dart, which in many cases sequentially functioned as a projectile and knife or other tool. These were likely damaged on hunting forays and resharpened or reworked at the temporary camp. Other dart points are clearly intended to be projectiles. Conversely, LP groups transported higher numbers of bifaces and chert blanks. Given the evidence of the transport of unfinished arrow shafts it is possible that these three items; bifaces, blanks and shafts may have been part of a mobile tool kit for projectiles. LP groups also manufactured a higher number of chert tools on site and likely scavenged resources from earlier occupations.

CHAPTER 5

LATE HOLOCENE FORAGING EFFICIENCY

Thus far this investigation has demonstrated through a metric discrimination of the projectiles that there was indeed a transition from the atlatl to the bow in north central Texas. Furthermore, it is evident that there are fundamental differences in design construction, maintenance, and use histories of the points. Even though it is likely that the stone points associated with both weapon systems were primarily utilized for large prey, the manner in which they were used was different in terms of recycling and expendability. Dart points were of sufficient size to be recycled, and the diminutive size of the arrow points suggests that they were intended for a single episode of use.

Design considerations indicate that there is a substantial difference in the relative cost of the projectiles, which could have affected the cost/benefit relationship between predator and prey. Beyond that, a physical comparison of the weapons indicates that the bow and arrow are likely to have the advantage in terms of velocity, accuracy, and distance while the situational comparison indicates potential advantages in portability, concealment, and rate of fire. Ultimately, the near global transition to the bow and arrow in the archaeological record implies that it was superior as the phenomenon transcended social, cultural and climatic boundaries. The ubiquity of its adoption in all ecozones indicates that the impetus for adoption was not dependent on a type of environment or size or species of prey as it was used in open and closed terrain, in temperate as well as arctic environs, and was adapted to hunt for all sizes of prey from small game and aquatic resources to the largest herbivores.

All in all, this global transition attests to the bow and arrows versatility and adaptability and one could logically predict that it would increase net acquisition rates of large and small animals and in turn increase population security. This raises the question "If the bow and arrow was not more efficient or advantageous why would people adopt it after generally employing the atlatl to procure their highest ranked protein and lipid resources for thousands of years?" Given the widespread trend of adoption, the impetus for the transition in the Upper Trinity River region would have to be considered from a global or at least regional scale; however, the portion of the archaeological record consisting of faunal remains can be evaluated to determine if there was an increase in foraging efficiency in the study area.

Optimal Foraging Theory

A considerable amount of archaeological research has been conducted utilizing optimal foraging theory borrowed from evolutionary ecology (MacArthur and Pianka 1966). These models predict the range and proportions of food items a predator will consume, as well as the location and duration of the hunt. They are based on the assumption from natural selection theory that an animal will feed so as to maximize its reproductive success or fitness (Hames and Vickers 1982). The models have been useful to archaeologists for elucidating subsistence change over an extended time scale (Broughton 1994, 1999; Butler 2001; Byers and Broughton 2004; Byers et al. 2005; Cannon 2000; Grayson and Cannon 1999; Janetski 1997; Nagaoka 2001, 2002a, 2002b; Simms 1987; Szutzer and Bayham 1996; Wolverton 2005).

These studies generally utilize the prey choice model (e.g. Stephens and Krebs 1986) to illustrate the relationship between hunter and prey and make predictions about the manner in which humans will respond to long-term changes in resource availability. The model assumes that hunters seeking to maximize efficiency will conduct an immediate cost benefit analysis on the decision, to pursue, or not to pursue, or to harvest, or not harvest a particular resource (Winterhalder and Kennet 2006). Furthermore, it stipulates that they will harvest higher ranked, low cost prey because it offers a higher yield per unit of energy expended (i.e., post-encounter return rate).

If encounter return rates with high ranked prey decline, lower ranked (less desirable) prey will be pursued or added to the diet as they are encountered. These ranks have been defined directly in ecology and ethnographic studies by measuring return rates and handling costs using a currency such as kilocalories an hour (O'Connell et al. 1988; Smith 1991) however, archaeologists are usually relegated to indirect measures due to the fact that the archaeological assemblages are only vestiges of past human behaviors.

Many archaeologists contend that body size (e.g. Broughton 1994, 1999; Griffiths 1975; Hames and Vickers 1982; Nagaoka 2002; Wolverton 2005) and prey speed (Stiner et al. 2000) are reliable proxy measures of the energetic return rate. The most common proxy is prey size, and it is the most appropriate here because it is assumed that the large prey was procured primarily with the bow and arrow. A faunal assemblage dominated by large high-ranked prey remains indicates a higher energetic return per unit of foraging time compared to an assemblage dominated by small low-ranked taxa. Basically, the caloric value of an organism is directly proportional to its weight. Some contend that body size is the "only valid, context independent, proxy measure of prey rank currently available to archaeologists" (Broughton 1994; 503). And it is likely the "most archaeologically visible dimension of prey rank" (Byers et al. 2005: 129).

Others have noted that prey ranks can be affected by advancements in procurement technology, which can raise the profitability of a low ranked resource (cf. Alvard and Kaplan

1991; Hames and Vickers 1982; Lupo and Schmidt 2005; Nagaoka 2002; Smith 1981 1991; Ugan et al. 2003; Winterhalder 1981b). Similarly, mass capture techniques such as buffalo jumps (Bement 1986; Frison 1991), drives, or nets for fish (Broughton 1999), or rabbits (Byers and Broughton 2004), can influence prey ranks as the prey are counted as a group instead of as individual prey. Basically the returns per capture are expected to be substantially higher than predicted by the size of the individual animal (Grayson and Cannon 1999; Madsen and Schmidt 1998) and the prey ranks can be adjusted to accommodate mass capture (Nagaoka 2002).

These models have detected declines in the relative abundances of high ranked taxa, termed resource depression (Charnov 1976) or intensification (Broughton 1994), either through a downturn in environment or overexploitation by humans (Butler 2000; Cannon 2003; Nagaoka 2002a; Stiner et al. 2000). Other studies have illuminated increases in foraging efficiency related to climatic amelioration (Broughton and Bayham 2003; Byers and Broughton 2004; Wolverton 2005) or technological improvements such as the gun, (O'Connell and Marshall 1989; Smith 1991; Winterhalder 1981a) nets for rabbit drives, (Steward 1938) or possibly the bow and arrow (Hughes 1998).

Overall, the aforementioned studies illustrate that there can be several possible mechanisms influencing prey choice such as environmental change, technology, or human demographics. This chapter will investigate the possibility that the bow and arrow in conjunction with the climate increased foraging efficiency during the Late Holocene in the Upper Trinity River. If there were an increase in precipitation and thus favorable habitat for preferred high ranked prey such as whitetail deer (*Odocoileus virginianus*) and bison (*Bison bison*) coincident with an improvement in procurement technology, the prey choice model would predict an increase in foraging efficiency.

Technological Efficiency Increase Background

The diet breadth model (Emlen 1966; MacArthur and Pianka 1966 Kaplan and Hill 1992) provides a theoretical framework to investigate the factors that render the bow and arrow more technologically efficient. This model divides the time spent acquiring a resource into two periods, search costs (encounter rates), and handling costs (post-encounter rate). Search cost is the time spent locating the prey such as waiting in ambush at a blind, while handling costs entail the time to pursue, harvest and process the prey after it is located. The bow and arrow could have affected both search and handling costs for high *and* low ranked taxa thereby increasing foraging efficiency of the inhabitants of the Upper Trinity River in the Late Prehistoric period.

Search Costs

The use of the bow and arrow could have affected search costs for two main reasons. First, the users could be more mobile in an effort to encounter prey because long dart shafts (152-183 cm) would not have to be carried. Ethnographic evidence indicates that these are sometimes stored at ambush locations to mitigate transportation costs (Greaves 1997). Arrows carried in quivers offered more potential for mobility and left hands free for other tasks such as carrying weapons or game (see Design Considerations).

Second, search costs for arrows were lower because they offered more concealment as the high arcing motion of atlatl would not have to be performed (cf. Blitz 1988; Frison 1978; Hames 1979; Christenson 1986). The front to back motion in drawing a bow is simply less conspicuous than launching a spear. Additionally, the bow can be used from a variety of positions such as kneeling or crouching, in what some have termed, flexibility in use position (Bergman et al. 1988; Christenson 1986; Hughes 1998). Attempts at concealment and close-range hunting in North America with the bow are well chronicled through eyewitness accounts which recorded universal techniques of luring animals in through calls, decoys or mimicking by wearing skins and shooting at animals (Catlin 1973; Hamilton 1982; Pope 1918; Speir 1928; Swanton 1942). All of the methods of hunting such as pounds, drives, stalking, and ambush were attempts to close the distance to prey (Mason 1893).

Additionally, the bows were generally designed to shoot in tight quarters at a close target (cf. Miller 2003). Even the most technologically efficient bows of North America, the Plains composite bows, were designed to shoot at bison from only 2-5 m on horseback. In summation, observational and theoretical evidence indicate search costs would be lower with the bow and arrow because it facilitated and increased the frequency of "point blank" encounters, increasing success rates. It allowed the user to maneuver into position and launch an effective arrow less conspicuously than the atlatl thereby reducing the amount of time spent searching for prey.

Handling Costs and the Bow

Handling costs would be lower with the bow than the atlatl because of the chances of the encounter being successful after prey had been sighted. Perhaps the foremost reason is that the weapon is more accurate due to increased velocity and a flatter trajectory (see Physical Comparison). In essence, the user does not have to adjust their point of aim due to the arch of the projectile. It is also backsighted, which can aid accuracy (Christenson 1986). Increased accuracy would lower handling costs by providing a more lethal weapon.

Just as search costs were reduced by allowing users to maneuver into effective position, handling costs were lower because success rates were higher at close range. Beyond the velocity of the projectile, proximity to target is the most the effective method of increasing accuracy. As mentioned in the Performance Characteristics Comparison, Old World archery had an evolutionary trend towards increasing efficiency to enable the user to shoot at objects farther and farther distances. The reasons for this are two fold. One was due to environment, as generally in the Old World they were hunting in broad gallery forests, as opposed to dense brush. Two, the general impression of warfare tactics in Europe is that they were conducted from a distance.

Conversely, bows from North America in general were designed for close encounters by allowing concealment in dense vegetation or on horseback. Ishi's bow (Pope 1918) in comparison to Oetzi the "Iceman" (Spindler 1999) from the Tyrolean Alps is a prime example of this trend as the former's weapons were from ~106 cm to 142 cm and the latter's bow was 192 cm. Even though Oetzi was 10 cm shorter in stature than Ishi, his bow was 50 to 90 cm longer. This is likely due to the context of the hunting methods (Miller 2003) as Ishi's preferred method was to crouch or kneel in dense brush and lure prey into shooting range (Pope 1918).

Similarly, Native American warfare tactics also were often conducted at close distance. With Plains tribes it was more "honorable" to get close and "count coup" than to take an adversary from a distance (Grinnell 1910); there was likely "prestige" associated with this as there was with big game hunting (cf. Hildebrandt and Maguire 2002). In general, the types of bows employed in North America were designed to allow for concealment and close accurate encounters. This combined with increased velocity (flatter trajectory) allowed for greater accuracy and thus lower handling costs after game has been encountered because success rates are higher.

Handling Costs and the Projectiles

Although stone dart and arrow points were used for the same task, the lithic analysis has demonstrated that there is a fundamental a difference in the manner in which this task was conducted. Darts were a curated projectile strategy that was generalized in function. They were of sufficient size that they were commonly recycled. The fact that 62% were reworked, and 44% were beveled in this sample, compared to 4% and 2% of the arrows respectively, suggest that and in some cases they were used for a cutting implement. This entailed the use of a detachable foreshaft and retrieval after projection. This suggests less mobility and situational flexibility, as they first had to be retrieved. The hunter was in a sense tethered to the projectile due to its relative value. The cost of the dart's stone point and shaft necessitated its retrieval, as they were more possibly more expensive than the immediate loss of hunting opportunity.

Conversely, expendable, replaceable, low cost arrows, carried in quivers offered a lower cost per shot and more potential for mobility. They required fewer raw materials, less labor and time for construction, and were less costly to transport. Perhaps foremost, hunters were free to pursue wounded prey or seek more encounters, instead of retrieving and recycling costly projectiles and shafts. Arrows would be sought after if it was convenient but their patterns of design and maintenance indicate that they were expendable and not commonly recycled.

Cost Benefit and Small Prey

It must be noted that low cost arrows likely affected the cost benefit relationship with small prey making them more profitable to procure for their low caloric return. It is often assumed that a substantial if not a majority of small game were procured through passive techniques such as snares, deadfalls, traps, weirs, poisoning of waters for fish, and smoking or digging of burrows for fossorial animals; however, the bow and arrow were commonly in use in areas with relatively low numbers of large game such as southwestern North America (e.g. Mojave) suggesting that they were used for small prey in those contexts. Additionally, the literature supports the contention that bows were employed for small prey with virtually all of the 79 cultures in Ellis's (1997) archaeological and ethnographic summary employing the weapon for both large and small game. Stone was too costly for this endeavor and other types of points are actually more efficient as they can be designed specifically to the prey (Miller 2005). For instance some were thatched on the tip to allow for a wider surface area for bird hunting (e.g. Ishi Pope 1918). Ethnographic studies indicate that there were several types of arrows carried in the quiver other than stone such as wood, bone, antler, gar fish scales, thorns and turtle claws each suited to different types of hunting or animals (Binford 1979; Pope 1918, 1925; Radin 1923; for a comprehensive list see Ellis 1997). Museum collections support this claim as well (Hamm 1999, 2002).

Griffin (1997: 281) states that Agta hunters carry 3 or 4 arrow types that serve different functions and that prey species and size, as well as condition of the animal affect choice of arrow. Sometimes different types of arrows are used sequentially, first, a dragline arrow then a killing arrow for large prey. Furthermore, small prey do not warrant the expenditure of expensive, multicomponent metal tipped arrows because they are not worth the risk of arrow loss, and the use of these points would be considered “overkill”. Also, since monkeys remove arrows, the Agta use “expendable” arrows. Thus it is apparent that the type and size of prey can influence the choice of the type of arrow; however, the cost or risk of loss in relation to the reward is an overriding factor in projectile selection.

Social Aspect

With a ready supply of low cost, organically tipped arrows, hunters could profitably take shots at small prey of low caloric return; children possibly could even have undertaken this. Catlin (1973: 32) accounts that in regards to the bow and arrow the "children's sinews were habituated to its usage since birth." It is illogical to surmise that unskilled, untrained hunters would be allowed to pursue costly high ranked resources; there is likely no better method to train hunters than small game.

There are numerous ethnographic studies that note resource selection often varies as a function of the age, sex, and composition of the task group (Bird and Bleige-Bird 1997; Hawkes et al. 1995; Hill et al. 1987; Hockett 2005; Lupo and Schmidt 2002; Weissner 2002). Essentially, children may focus on lower ranked resources that are easily handled (Bird and Bleige-Bird 2000). Similarly, since young children would lack the strength necessary to draw bows of sufficient poundage to procure large prey, they would have been relegated to hunting small prey. Thus, the role of children in the foraging has been established and the transition to the bow and arrow may have increased their contribution to the diet via an increase in small game.

Late Holocene Upper Trinity River Background

The study area is located in the Eastern Cross Timbers physiographic region near the ecotone with the Fort Worth Prairie to the west and the Blackland Prairie to the east (Fig. 1.2). The sites are located on terraces and in alluvial deposits on the Elm Fork Trinity River. It is likely that the vegetation communities have remained consistent in type as they are controlled by edaphic conditions of the soil. The ecotonal location allowed inhabitants of all periods to exploit resources from both biotic provinces; grassland taxa could found in the prairies (e.g. bison, pronghorn, jackrabbit), wooded edge dwellers on the margins (e.g. whitetail deer, terrapin, turkey) and riparian denizens in the Cross Timbers (raccoon, beaver, squirrel) (Table 11). All components contain a mixture of prairie and woodland faunas illustrating the physiographic mosaic.

Table 11. Identified Faunal List. Not an exhaustive list. Habitat noted as well.

Taxa	Habitat
Catfish	A
Drum	A
Bass	A
Sunfish	A
Toad	V
Frog	A
Musk Turtle	A
Mud Turtle	A
Pond Turtle	A
Map Turtle	A
Diamond Back Terrapin	G, WE
Slider Turtle	A
Box Turtle	G, WE
Softshell Turtle	A
Copperhead	A
Lizard	G, W
Red Tailed Hawk	G, WE
Turkey	W, WE
Bobwhite quail	G, WE
Prairie Chicken	G
Eastern Cottontail Rabbit	W, WE
Black Tailed Jack Rabbit	G
Gray Squirrel	B
Fox Squirrel	W, B
Beaver	A
Pocket Gopher	G
Pocket Mouse	G
Cotton Rat	G
Vole	G
Raccoon	B, W
Skunk	WE
Mink	B
Dog	V
Coyote	V
Whitetail Deer	WE
Pronghorn	G
Bison	G

Key:

A = (rivers, swamps, marshes) B = bottomlands (riparian habitats)
G = grasslands (brush, prairies) V = various (more than one habitat)
W = woodlands (deciduous or pine forests) WE = wooded edges (open meadows, parklands)

All of the sites in the area are temporary hunting camps used by mobile hunters and gatherers that practiced broad-spectrum foraging (Ferring and Yates 1997, 1998) consisting primarily of three taxa, whitetail deer (*Odocoileus virginianus*), lagomorphs (*Sylvilagus sp.* and *Lepus californicus*) and turtle (e.g. *Terrapene ornata*). Botanical preservation is not favorable; however, there are no signs of cultivation. Floral resources consisted of processing of non-domesticate nuts and seeds as evidenced by grinding implements.

Whitetail deer, bison, and pronghorn (*Antilocapra americana*) are the highest post encounter return rates in the area. It appears that whitetail deer were the primary high ranked source exploited through time and that bison increased in frequency through the period (Ferring and Yates 1997, 1998). There are no signs of mass capture as the geomorphology of the area is likely not suited to drives, jumps or corrals. It is possible that some animals could have been opportunistically driven into the river or mud as with some southeastern cultures (e.g. Swanton 1911). It is likely that most hunting for large prey was conducted by luring animals into range through mimicry, ambush along trails, or stalk upon encounter.

It has been noted that climate change was an important factor in diets, body sizes, and biogeographic distributions of prey (Byers and Broughton 2004; Wolverton 2005) and any reasoned investigation must consider environmental fluctuations. Unlike some areas such as the Wyoming Basin (e.g. Byers et al. 2005) there has not been a great deal of paleoenvironmental or archaeological investigations in the Upper Trinity River region of north central Texas. There are no pollen records from the vicinity but there is general consensus that the Middle Holocene (7500-4000 bp) was a period of decreased overall biomass presumably caused by lower annual precipitation (Dillehay 1974; Ferring and Yates 1997, 1998; Graham 1987; Hall 1982, 1990, 1992).

And there is little argument that in the beginning of the Late Holocene period, roughly coincident with the Late Archaic cultural period (3500 bp), that there was an increase in biomass and in human occupation due to increased annual precipitation (Ferring and Yates 1997, 1998). However, there are two distinct lines of thought on precipitation levels and the climate of the Late Prehistoric period (1250-500 bp) and what affects that would have had on prehistoric game populations, in particular bison.

Bison were likely never entirely “absent” in the general region in the Late Holocene (cf. Dillehay 1974; Ferring and Yates 1997, 1998). Components of all time periods contain some potential bison remains (potential in that some specimens compare favorably); however, there is evidence of a general increase in frequency through time at sites DN381 and DN372 from Lake Lewisville (Ferring and Yates 1998: 151). The highest frequencies from the Upper Trinity and surrounding region are in the later part of the LP period. The cause of this regional trend has been debated; one group of researchers attribute this to drier climates that favor the propagation of short grasses, which they contend would allow bison to migrate into the region (Hall 1988, 1990, 1992; Lynott 1977, 1981). Though some of the evidence is based on pollen and molluscan data (Hall 1982, 1990), Ferring and Yates (1998: 151) point out this view is based on “stacked assumptions” and circular reasoning about bison’s preferred food, of short, warm season grasses, in particular, C_4 species such as Buffalograss and its southern Plains co-dominant, Blue grama. Hall and Lynott assume that an increase in bison frequency must indicate an increase in short grasses afforded by a drier climate.

The second group of researchers contends that bison populations are positively correlated with increases in annual precipitation (Dillehay 1974; Ferring and Yates 1998; McDonald 1981; Van Vuren and Bray 1986; cf. Byers and Broughton 2004). Overall trends in bison populations on the Great Plains are rainfall dependent (McDonald 1981) and it is illogical to surmise that their numbers would increase as precipitation decreased.

The Middle Archaic occupations in the study area (41DN102) contain only four elements that "compare favorably" with bison even though significantly drier climates prevailed (Ferring and Yates 1997). Essentially, if there is more effective precipitation there should be an increase in prairie grasses suitable for bison not less (Ferring and Yates 1998: 26). Forage quality and environmental productivity are positively correlated with effective precipitation and soil moisture in the arid West (e.g. Douglas 2001; Murphy 1970) and that should apply here as well.

It is well established that other artiodactyls such as mule deer (Odocoileus *hemionus*), pronghorn (*Antilocapra americana)*, bighorn sheep (*Ovis Canadensis*), elk (*Cervus elaphus*) are sensitive to variation in climate and changes in precipitation (Byers and Broughton 2004, and references therein). Although there has been a lack of research on whitetail deer, it is also expected that their populations would increase in response to higher levels of effective precipitation as well. Much of their daily requirements are met by moisture in the plants they consume, sometimes in the form of dew (Lee Rue III 1997). With whitetails being consummate edge browsers their populations should positively correlate with increases in habitat related to more precipitation. Essentially, there is little evidence that browsing or grazing populations would not increase in response to higher levels of rainfall.

Evidence for climatic amelioration in the Late Holocene, specifically the LPII period, comes from microfaunal and molluscan data (Henry 1995) as well as stable isotopes (Humphrey and Ferring 1994). And although there are no pollen records from the north central Texas region, there is data from Ferndale Bog in the Ouachita Mountains of southeast Oklahoma (Holloway 1993) and from Boriack Bog in central Texas (Holloway, Raab, and Stuckenrath 1987) that indicate increases in prairie biomass in the Late Holocene. Additionally, 58 lacustrine, spring and pedogenic carbonate samples of isotopic data from the Aubrey Clovis site (Ferring and Yates 1998, 2001) in north central Texas indicate moister conditions. Overall evidence of climatic amelioration in the Late Holocene, and in particular the LPII period, are supported indirectly with increased abundance of bison and whitetail deer bones at archaeological sites and directly with a host of environmental data.

The trend towards a greater utilization of whitetail deer appears to be regional as subsequent to the Mid Holocene Altithermal human populations along the margin of the Great Plains and the eastern woodlands shifted from a broad-spectrum diet to more of a specialized focus (Wolverton et al. 2008). There is a similar trend at Wilson-Leonard in central Texas (Collins 2004) and along the southeast Texas coast (Wolverton et al. 2008). Most of the sites in the Upper Trinity River are located at the grassland margins of the Fort Worth and Blackland prairies and not centrally located in the Eastern Cross Timbers suggesting more of a focus on hunting whitetail than mast exploitation (cf. Ferring and Yates 1998). The faunal assemblage from Lake Ray Roberts supports this conclusion, as deer frequencies in the LP are about 10% higher than for the LA samples (Ferring and Yates 1997: 300).

Why this Study Area is Appropriate for this Research

This study area and archaeological assemblage is appropriate for this task several reasons. Foremost, the sites span the period of the introduction of the bow and arrow (4500-1250 bp) and it has been established through a metric discrimination of the projectiles that there was a transition to the new weapon. Also, there is substantial ethnographic and ethnohistorical evidence that stone points were used almost exclusively for the procurement of large prey (Ellis

1997) and these assemblages are dominated by stone dart and arrow points (Ferring and Yates 1997, 1998). Thus, it logical to associate the stone points to the procurement of high ranked prey in the assemblages

Furthermore, the sites are appropriate because they are considered temporary hunting camps with some possibly approaching a hamlet (Ferring and Yates 1997,1998). And there are no obvious signs of a change in site function (e.g. sedentism or farming) that might influence accumulation of the faunal assemblage. For instance, sedentism or "central place" could lower local prey availability resulting in resource depression (Cannon 2000; Charnov 1976), which would affect a diachronic comparison of the technological efficiencies of the weapon systems. Additionally, the overall compositions of the lithic assemblages from the LA and LP suggest a continuity of cultural groups. Essentially, there are no indications of the migration of a new cultural group, suggesting that the same basic social groups used the sites intermittently through the Late Holocene to procure an array of resources. Thus, these sites contain evidence of the transition from the atlatl to the bow and arrow and it is logical to assume that the sites were used in relatively the same manner providing a plausible basis for a technological comparison. It is assumed that the comparison between the sites will be sufficiently reliable because the sites were excavated with the same methods and procedures. Similarly the same person conducted the faunal identifications (Ferring and Yates 1997, 1998). However, this analysis must be conducted with considerations of climatic perturbations and available habitat, as there is little doubt that precipitation levels have a direct effect on artiodactyl populations and thus prey availability.

Upper Trinity River Archaeofaunas

The data that are used to test the hypothesis that there was increase in foraging efficiency in the Late Holocene related to technological change are from north central Texas along the Elm Fork of the Upper Trinity River (Fig. 1.2) (Ferring and Yates 1997, 1998). The sites were excavated as part of mitigation projects for the construction of Lewisville and Ray Roberts reservoirs. They span the Middle Archaic through the Late Prehistoric periods and most sites are multicomponent; however, there are some, such as CO150, that are discrete temporal occupations (Table 12). All 12 of the sites contain requisite faunal and lithic assemblages. The 28 components were assigned to cultural period by radiocarbon dates (21 have ^{14}C dates) and cross dating using temporally sensitive projectile point types and the presence/absence of ceramics as well as temper composition. This study utilizes the cultural designations of the excavators in the initial publications (Ferring and Yates 1997, 1998) that are based on Prikryl's chronology (1990). It is assumed that the lithic assemblages are correlated with the faunal assemblages.

Table 12. Site List with chronology and sample size. All dates are in years before present. (Data sourced from: Ferring and Yates 1997, 1998). Chronology = Middle Archaic (MA); Late Archaic (LA); Late Prehistoric (LP). Location = Lewisville Lake (LL); Ray Roberts Lake (RR).

Site List	Blocks or Levels	^{14}C Dates	Cultural period	Location	Sm. Game	Lg. Game
41DN 26	1 - 9	620, 580, 564	LPII	LL	1233	900
41DN 26	10 - 15	521	LPII	LL	329	358
41DN 27	1 - 14	525 and 668	LPII	LL	1997	1658
41DN 372	1 - 7	610	LPII	LL	9189	2309
41DN 381	12 - 19	490	LPII	LL	382	263
41CO 141	2 - 8	759	LPII	RR	274	182
41DN 381	20-22	790	LPI/II	LL	520	287
41DN 99	2 - 7	528 and 1,268	LPI/II	RR	1154	587
41DN 197	22 - 24	1,129	LPI	RR	40	48
41DN 103	1 - 5		LPI	RR	351	83
41DN 102	Bl.1 1 - 5	1,230	LPI	RR	703	414
41DN 102	Bl.3 2 - 10		LPI	RR	186	89
41DN 372	8 - 10		LA/LP	LL	6127	843
41CO 141	2 - 8	1,282	LA/LP	RR	1523	572
41DN 346	1 - 7		LA/LP	RR	78	67
41DN 99	8 - 11	1,406	LA	RR	629	262
41DN 102	Bl.1 6 - 9	1,980	LA	RR	91	73
41CO 150	Bl. 1	1,985 and 2,750	LA	RR	352	259
41CO 150	Bl.2 A2	1,680	LA	RR	824	231
41CO 150	Bl.2 A3	1,985	LA	RR	460	92
41CO 150	Bl.2 B2	2,750	LA	RR	1161	533
41CO 150	Bl.2 B3	2,600	LA	RR	190	83
41CO 150	Bl.2 B5	2,320	LA	RR	1939	63
41CO 150	Bl.2 B6	2,910	LA	RR	119	194
41CO 144	A2 - A15		LA	RR	919	351
41CO 144	B0 - B7	2,284	LA	RR	56	108
41DN 346	8 - TU		LA	RR	87	87
41DN 102	Bl.2 11 - 24		MA	RR	383	140

Although excavated volumes vary, faunal elements were recovered at all 12 sites by dry sifting through 1/4 and 1/8-inch screens with similar excavation techniques (Ferring and Yates, 1998) and by the same faunal identifier. The number of identified specimens (NISP) is used as the measure of taxonomic abundance in the analysis. Though its limitations are well documented (e.g. fragmentation, interdependence etc.) (Grayson 1984) it is the most commonly used measure and it allows for a larger sample size. With the aforementioned considerations, all further statistical analyses are relegated to an ordinal-scale level of measurement and thus, only nonparametric tests such as Spearman's rho and scattergrams are appropriate.

To monitor fluctuations of the relative abundances of high ranked to low ranked prey as based on body size (Broughton 1994; Byers et al. 2005; Cannon 2003) the faunal data were grouped into two size classes, large and small. It is assumed that assemblages dominated by large high ranked prey will indicate a higher level of foraging efficiency. Taxa that are identified as whitetail deer, pronghorn and bison as well as large indeterminate fragments are included in the large class (Table 11). Other than recent intrusive species such as armadillo (*Dasypus novemcinctus*), all taxa other than deer and bison size were grouped into the small size class. This would consist of lagomorphs, terrapins, fossorial animals, as well as birds and aquatic species. It is assumed that these animals are roughly of the same size and caloric value; however, there are substantial size disparities that exist between the high and low rank taxa. For instance, lagomorphs range in size from .6 – 2.8 kg, while whitetail deer weigh from 22 to 180 kg. This allows for a larger sample size, and beyond the ubiquity of small prey such as turtle and lagomorphs, there is no indication that they were focusing specifically on any particular species. In lieu of a high ranked prey encounter, any of the small species may have been procured upon sight. The fact that turtles and terrapins are possibly overrepresented due to the ease of identification render an increase in large bodied taxa all the more significant.

As Kaplan and Hill (1992) note, ethnographically, some foragers search for all potential resources simultaneously, some set out with specific resources in mind, and some follow strategies that fall in between (cf. Smith 1991). Although it is likely that a substantial portion of the small prey were procured through passive techniques (e.g. snares, weirs) as encounters with high ranked prey were pursued, many of these species could be procured with arrows through low material cost and little effort. Ishi regularly took shots at small game and was proficient at quail sized targets from 25-35 m (Pope 1925).

Rodent bones are included as dietary items, and although some could contend that they are non-cultural in origin, there is evidence that they were exploited at least in part by element representation at 41DN102 (Ferring and Yates 1197: 270). Other taxa such as salamanders and frogs could be contested as well, but the view here is that these were broad-spectrum foragers, and that the overall the assessment of subsistence practices are strengthened by more data. If this methodology were to have an influence on the analysis it would be to overrepresent the relative contribution of low ranked prey to the diet; thus, lowering the measure of foraging efficiency. It will be shown that the inclusion of small prey of possible non-cultural origin does not negatively affect the assessment of foraging efficiency.

Measuring Prey Choice

Two different indices were constructed from the large and small prey classes to monitor foraging efficiency in the Upper Trinity River. These models can be used to predict that increases over time in the archaeological abundances of large-bodied prey relative to the abundances of small-bodied prey. Both are based on the large prey to small prey, high to low caloric benefit methodology that is common to foraging theory (Broughton 1994; Byers and Broughton 2004; Cannon 2003; Wolverton 2005). If the extractive efficiency of Late Prehistoric hunters increased relative to atlatl using groups of the Late Archaic, these measures of taxonomic relative abundances should increase over time. Index values that approach towards, 1.0 indicate a higher frequency of high ranked prey relative to low-rank prey; whereas, values closer to 0.0

indicate lower frequencies of high-rank taxa relative to low-rank taxa. To display temporal trends in Upper Trinity River prey selection the indices were calculated for the 28 components. These were aggregated and averaged into six time periods ranging from the Middle Archaic to the Late Prehistoric II (Table 13). These are assumed to be time averaged behaviors of hunters that were on a "round" in this region. The first index is the Artiodactyl Index and the second is the Medium Artiodactyl Index (MAI) these will be discussed in turn.

Table 13. Artiodactyl Index values and NISP of the sample. Note the highest values are in the LP. (Data sourced from: Ferring and Yates 1997, 1998).

Cultural Period	Large Game (NISP)	Small Game (NISP)	AI
Late Prehistoric II	6060	14653	0.29
Late Prehistoric I / Late Prehistoric II	642	1158	0.35
Late Prehistoric I	634	1280	0.33
Late Archaic / Late Prehistoric	1092	6478	0.14
Late Archaic	2336	6697	0.25
Middle Archaic	140	383	0.26

The Artiodactyl Index (AI) is a calculation of *all three* of the large-bodied artiodactyls encountered in the Upper Trinity area, deer, bison, and antelope relative to all small-bodied prey, it is calculated as:

$$\sum \text{NISP } \textit{Artiodactyl Remains} \div$$

$$\sum (\text{NISP } \textit{Artiodactyl} + \text{NISP } \textit{Small Prey Remains})$$

Figure 5.1 plots the AI for the sites through time. Observational evidence indicates that although there are marked fluctuations, there does appear to be a tendency towards an increase through time. However, this is not reinforced by a Spearman's correlation coefficient as a moderate correlation was found that was not significant (r (4) = 0.600, p = 0.208) (test was two-tailed). Further, the highest values are during the LP in periods 4 and 5 period when the bow and arrow were in use in the Upper Trinity River region (Table 13) suggesting that it was a factor. The use of bison, deer and antelope in relation to all small game certainly do not decrease through time, as all three LP values are higher than the LA and MA values. Bear in mind that the small game sample is possibly overrepresented due to the inclusion of gophers, wood rats, cotton rats, snakes, voles and others that are possibly intrusive to the site. There is plenty of evidence that those taxa were exploited at times (Janetski 1979; Lyman 1992; Schmitt and Lupo 1995; Stiner et al. 2000); although given the size of the small game sample (n= 30,649), there are likely some included that were not food items. In spite of their inclusion there does appear to be a general trend towards increasing abundance of artiodactyls in the periods with confirmed use of the bow and arrow.

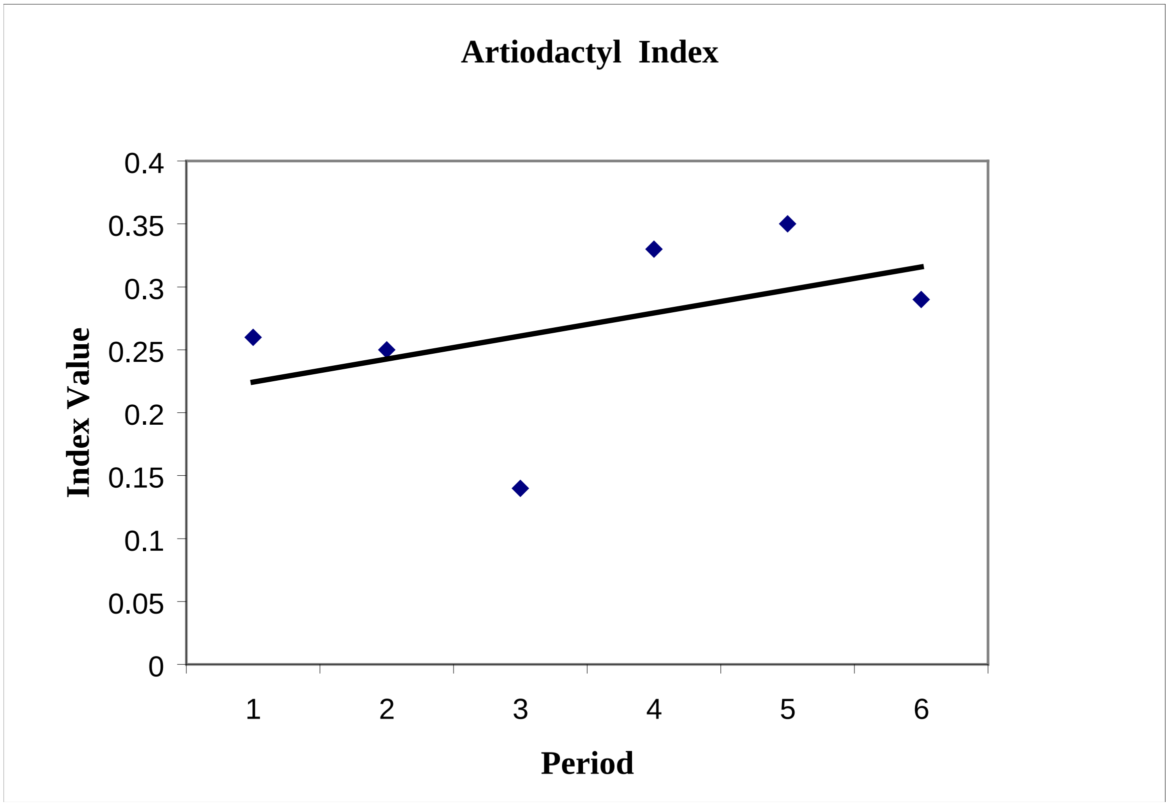


Figure 5.1. The relative abundance of artiodactyls in comparison to small game. Note the highest values are in period 4 (Late Prehistoric) and later. Although there is a trend towards higher artiodactyl abundance, overall these values are not high (.35 is the highest in period 5, LPI/LPII) indicating that small prey was always an important resource. The highest values are in the periods when the bow and arrow were in use.

One concern with this type of analysis is that the values of the AI can vary according to sample size (Cannon 2001; Grayson 1984; Janetski 1997; Wolverton 2005). To explore this possibility, a Spearman's correlation was calculated examining the relationship between ∑NISP of the artiodactlys and small game with the index. The resulting r-value (r (4) = 0.600, p = 0.207) (test was two-tailed) indicates that the index does not vary with the size of the assemblage.

The second measure of foraging efficiency is the Medium Artiodactyl Index (MAI), which charts the relative abundance of artiodactyls that consist of whitetail deer (*Odocoileus virginianus*) and antelope (*Antilocapra americana*) in relation to all small prey.

$$\sum \text{NISP Medium Artiodactyl Index } \textit{Remains} \div$$
$$\sum (\text{NISP Medium Artiodactyl Index} + \text{NISP } \textit{Small Prey Remains})$$

This is basically the previous index with the deletion of the bison sample (Table 14). Its purpose is to simply examine what effects that this large high ranked prey had relative to the deer sized prey. Essentially, is there evidence of an increase in foraging efficiency beyond the addition of bison to the diet? It must be noted that even though pronghorn are included their contribution is not substantial. Their highest frequency is 15 elements at 41CO144 but their mere presence, although small, necessitated that the faunal identifier relegate unidentified mammals of that size class to a pronghorn/deer indeterminate category. Their inclusion allows for the addition of that indeterminate category and thus provides a substantially larger sample size. Figure 5.2 plots the MAI for the sites through time. It appears that the there is little deviation from the previous analysis. The only change in index values is a decrease in periods 4-6 during the LP. The three highest values are still in the LP, although the LPII dropped from .29 to .26, placing it equal with the Middle Archaic. Overall, the MAI visually indicates an increase in the abundance of medium sized artiodactyls (deer and pronghorn) relative to small prey in the LP period particularly in LPI and in the LPI/II transition.

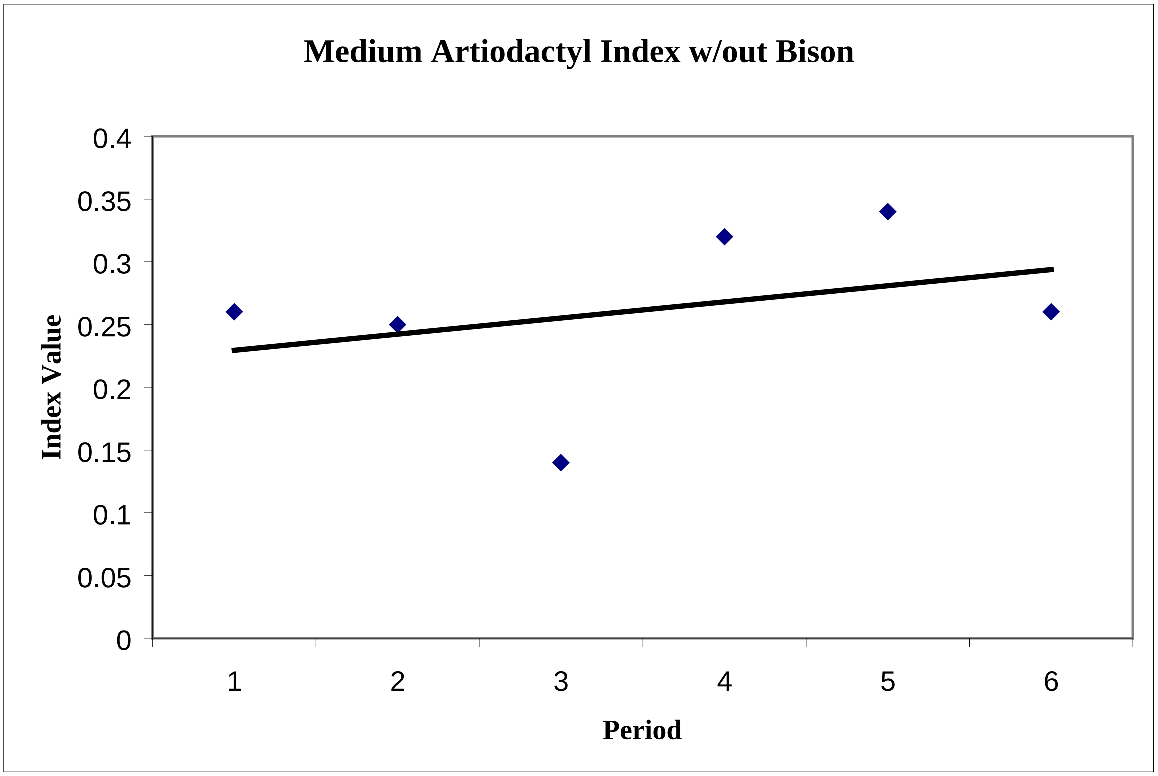


Figure 5.2. The relative abundance of medium artiodactyls in comparison to small game. This sample is without bison in the index. Note once again that the highest values are in periods 4 (LP), and 5 (LPI/LPII). The deletion of bison in the sample does not appear to have a substantial effect on the overall trend however the value in period 6 (.26) (LPII) is equal with period 1, Middle Archaic sample. The highest values are in the periods when the bow and arrow were in use.

Table 14. Restricted Medium Artiodactyl Index values and NISP of the sample. This sample is noteworthy due to the deletion of bison. Note the highest values are in the LP and later. Although the Late Prehistoric II value is equal with the MA (Data sourced from: Ferring and Yates 1997, 1998).

Cultural Period	Large Game (restricted) (NISP)	Small Game (NISP)	MAI
Late Prehistoric II	5092	14653	0.3
Late Prehistoric I / Late Prehistoric II	619	1158	0.3
Late Prehistoric I	630	1280	0.3
Late Archaic / Late Prehistoric	1089	6478	0.1
Late Archaic	2331	6697	0.3
Middle Archaic	136	383	0.3

As with the AI, the MAI was checked to determine if it correlated with sample size. A Spearman's correlation was calculated examining the relationship between ∑NISP of medium artiodactyls and small game with the index. The resulting *r*-value (r (4) = 0.429, p = 0.397) (test was two-tailed) indicates that the index does not vary with the size of the assemblage.

Discussion

The empirical data presented here suggest that there were indeed changes through time in Late Holocene artiodactyl abundances. Though there is no statistical correlation between the indices and time, a visual inspection suggests that there is a trend towards greater artiodactyl abundance after the LA/LP transition (Figures 5.1, 5.2). More specifically, after the Middle Archaic, index values of the AI and MAI actually decrease until the LP period and the introduction of the bow and arrow at ~1250 bp. This suggests that large prey procurement was declining until after the LA/LP transition. The highest values are in the LPI and LPI/LPII transition periods. The trend of an increase in foraging efficiency after the adoption of the bow and arrow has been predicted because of greater accuracy, portability and concealability as well as the global transition to the weapon.

The increase in the relative abundance of large game is even more relevant in light of the fact that the bow and arrow likely increased small game procurement. The bow's association with small game hunting is well documented (Ellis 1997 and references therein; Pope 1918). Arrows are essentially more cost effective to use for small game. Less time, labor, and raw materials would be invested and the fact that they were relatively expendable meant that hunters could take shots at game of low caloric return with less cost compared to the dart. These would not require stone points and can be used on encounter by mobile hunters or to train small children. Given that the new technology may have raised the profitability of some low ranked resources, such as lagomorphs, quail, raccoon, it is even more significant if there is an increase in the relative abundance of large game.

Some researchers have suggested that in the Great Basin, the adoption of the more efficient bow and arrow could have contributed to the decline of large prey, in particular, deer and mountain sheep that are taken primarily by encounter hunting (Janetski 1997; Madsen 1986). Others contend that resource intensification in this region was well under way before the introduction of the new technology (Broughton 1994b; Speth and Scott 1989). While it does appear that resource intensification was taking place here before the arrival of technology, as AI and MAI values are declining, subsequent to arrival, foraging efficiency actually increases.

This trend towards an increase in whitetail utilization is not specific to this area, as subsequent to the xeric Mid Holocene, human populations exploited them in higher frequency along the prairie-plains margin with eastern woodlands (Wolverton et al. 2008). The people in the Upper Trinity area lived precisely along that ecotone and it appears that the start of the trend coincided with the arrival of the technology. Other than the fact that the regional trend towards a focus on whitetail deer is subsequent to the Mid Holocene, the precise timing for the onset of the trend has not been established for a broad geographic area. It may be fruitful to more precisely substantiate the start of the increase in whitetail abundance to determine if it correlates with the arrival of the technology in those areas or climatic amelioration.

There is little doubt that the environment is an overriding factor on wild game populations. Any diachronic assessment of technological efficiencies must account for environmental conditions. Although there are no stratified archaeological sites (or pollen) allowing for detailed climatic reconstructions of the Upper Trinity River, alluvial histories, as well as a host of other environmental data, indicate that the adoption of the bow at ~1250 bp was roughly coincident with climatic amelioration associated with higher precipitation levels (cf. Ferring and Yates 1993, 1997, 1998 Henry 1995; Humphrey and Ferring 1994). Obviously this confounds an assessment of which technology was more efficient, the atlatl or the bow, because index values in the LP period could be the result of an increase in favorable habitat for deer and bison. With a more efficient extractive technology and climatic amelioration, optimal foraging theory would predict an increase in foraging efficiency, which is substantiated by the AI and MAI (Figures 5.1, 5.2).

The increase in artiodactyl abundance in the LP period can be attributed at least in part to higher availability as a result of more favorable habitat. Some have used the increase in bison frequencies in the LPII as a proxy for an increase in aridity in the region (Hall 1988, 1990, 1992; Lynott 1977, 1981). Those claims are difficult to substantiate given that whitetail deer, a consummate edge browser, increase in abundance in the archaeological assemblages as well. It should be noted that although there is a general trend towards an increase in the artiodactyl abundance in the LP, as compared to the LA, and MA, there is not a specialized focus as the highest value is .35 in the transitional LPI/LPII period. This indicates that small game were always an important resource.

Conclusion

Although it can be inferred from the near universal supplantation of the atlatl that the bow and arrow replicated its primary task, the procurement of large game, paradoxically, it was likely, also better suited to hunting small game. The large size of darts was somewhat overkill in terms of matching the “caliber” to the size of small game. Furthermore, it is possible that their manufacturing and raw material costs were too high in relation to the benefit from an animal of low caloric value. Despite this, there is still a trend towards increasing artiodactyl usage in the Late Prehistoric period. It is difficult to differentiate the effects of an increase in technological efficiency or a more suitable climate for large game. They are both regional in scope, and overall the issue should be dealt with on that scale, using from data from local regions to support broad geographic conclusions.

In short, although there does appear to be climatic amelioration, and a corresponding increase in harvest by humans, greater abundances in LP assemblages must be attributed in part to an increase in technological efficiency related to the bow and arrow. It is assumed that subsistence technologies compete with one another on the basis of extraction efficiency. If technology changes, return rates, or extraction efficiency must also change (Grayson and Cannon 1999: 146). Given that the aggregation method used here may overrepresent small game and that the weapon also likely increased the profitability (lower handling cost) of procuring them, an increase in high ranked species is all the more significant. Hypothetically, if a more efficient hunting technology were adopted with a concomitant increase in favorable habitat, the prey choice model would predict an increase in foraging efficiency and that is substantiated by this research.

Overall, there are several implications or inferences that can be gleaned from the transition. Essentially prehistoric groups selected the weapon that provided them with the highest probability of striking vital organs, as opposed to one that offered the greatest depth of penetration. With low velocity weapons that kill by inflicting hemorrhaging, it is evidently more advantageous to be on target, than have deeper penetration in a non-lethal area. There was selective pressure on the weapon that allowed for closer, more accurate encounters. Greater accuracy simply increases success rates and in turn population security. This mode of hunting by seeking “intimate encounters” is somewhat by choice and is akin to, or has precedent in, the manner in which warfare was conducted for many tribes, especially on the Plains. It was viewed as more “honorable” to have face-to-face confrontations than to strike from a distance (cf. Grinnell 1910). Thus the need for a close shot to increase hunting, and in turn reproductive, success rates was possibly socially reinforced with customs such as “counting coup”.

CHAPTER 6

CONCLUSION

In summation, this research is an investigation of the technological transition from the atlatl to the bow and arrow with a focus on potential effects on the diet. It has been conducted through a middle range theoretical approach (Binford 1981), that has utilized information and data from a variety of sources to provide theoretical warrant for the inferences made about this transition along the Upper Trinity River in north central Texas. To provide context, evidence was gleaned from a global database that consisted ethnographic and ethnohistorical accounts, as well as archaeological literature. Additionally, actualistic research conducted by the author in terms of hunting with "primitive style" weapons, as well as their manufacture, was of great benefit in the overall assessment.

This transition was a global phenomenon that crossed all ecological zones and transcended all cultural levels from simple hunter-gatherers to complex societies. The actual reasons or impetus likely vary according to context and would have to be dealt with on a regional scale. That perhaps is a testament to the weapons versatility, flexibility and adaptability. The archaeological literature supports this contention as well, with there being disagreement on whether the weapon is more suited to large or small game. It was broadly appropriate for all types of game, in addition to warfare. The data from north central Texas has been used to elucidate clues about the transition. Although they are specific to this area it is assumed that they can provide information about the transition as a whole.

The contextual background investigation has revealed that there are several potential advantages of the bow and arrow. Though there are extant groups that employ the weapon, these are in general, considerably different in that they use metal tips and often poison. Efficiency in a prehistoric context is not directly observable and must be inferred**;** however, empirically it can be demonstrated that the bow and arrow generate higher velocities, which translates into greater accuracy as a result of a flatter trajectory. Theoretically, it can be assumed that it was more portable due to the shorter length of the arrow in relation to the dart. It is likely that it offered more concealability because the high arcing motion was not required allowing for closer encounters. The preponderance of the chronicled methods of hunting and warfare, as well as the design of the bows in North America, indicate a preference or selection for those that were suited for more intimate accurate encounters. This is reinforced by the general impression of the Old World hunting and warfare techniques that also mimic each other, in that evolutionarily, there is a trend towards weapons that are suited to shooting at targets from farther distances. Overall, methods of use and design characteristics can aid in the identification of selective pressures that are operating on the evolutionary development of weapons systems.

With a complete lack of surviving spearthrowers or bows from the general region, the investigation has centered on the lithic assemblages, and more specifically the stone points, to identify the presence of and the differences between the weapon systems in north central Texas. Design theory has been used in this endeavor as it focuses on the constraints on tool design construction and morphology. It postulates that these “are specific behavioral responses to problems encountered in a natural or cultural context” (Odell 1996: 8) and that these principles can “allow the hunting strategies and other behavior of prehistoric hunters to be inferred from the design of their hunting weapons” (Bleed 1986: 738). Thus, it is ideal for this investigation.

Size Disparities

The evidence indicates that there are fundamental differences in almost all aspects of the ontogeny of dart and arrow points, from manufacture, to use, maintenance and discard. The underlying reason for these differences, as represented by the lithic assemblages, relates to the discrepancies in size between dart and arrow points. The properties of the fracture mechanics of stone are uniformitarian, in that processes that operated 2 million years ago are still in effect at present; similarly, it is assumed the gravitational forces governing low velocity projectiles such as the dart and arrow also remain in effect. Thus, the differences in the propulsive requirements of bow and spearthrower constrain the size of the projectiles that can be tolerated with the weapon systems. Arrows must be sufficiently flexible to bend around the handle of a bow, a phenomenon known as archer's paradox. Darts are not under this constraint and are propelled by a series of transverse oscillating waves that traverse the length of the shaft and back again, thus launching the dart away from the user. They can be substantially stiffer than arrows because they do not have to bend around the handle of the bow. Essentially, the inherent propulsive requirements for the weapon systems of the spearthrower and the bow allow for a different range of possible shaft sizes with dart and arrow points.

In the early stages of the investigation of the large point, small point, dart to arrow dichotomy, the "obvious" differences in size were explained commonsensically by the notion that the arrow requires small light points to maintain balance. This is only partly the case, as although the technology requires a smaller point than the dart due to spine requirements of the propulsive devices, a substantially heavier point can be employed. For instance, the mean arrow point weight from the Upper Trinity River is 0.6 g (*n*= 322) while the author has dispatched 8 whitetail deer with "primitive style", Osage orange bows using metal tips that weighed 8.7 g

(125 grains). Thus, there is a disconnect between what was used and what could potentially be used in terms of weight. The 8.7 g metal points are actually heavier than the 4 g mean (*n*= 249) for the dart points in the assemblage. These are considered standard size for modern bow hunters that use primitive style bows in a 45 to 65 lb. range, and it suggests that the flight requirements of arrows do not necessitate "tiny" points that weigh less than a gram; those factors can potentially be accommodated by adjusting shaft length, barrel tapering, fletching size, or other parameters. Their use likely relates to penetration. While the metal points described above are heavier by several grams, they inherently have a small cross sectional perimeter. Stone points that weigh 8.7 g would have a cross section that would impede penetration with a weapon that possessed the propulsive abilities of the bow.

The fundamental disparities in the size of the stone dart and arrow points have been used in this analysis to confirm the presence of the weapons in the assemblages. A neck width analysis of 575 projectiles indicates that there was indeed a transition that occurred at ~1250 bp. Furthermore, this research suggests that the traditional typology for this region (Prikryl 1990) is adequate for the identification of dart and arrow points.

K vs. *r* Strategy for the Projectiles

The size disparities of the projectiles create fundamental differences in their ontogeny, starting with manufacture. Darts generally require bifacial reduction while arrow points usually only require pressure flaking of a flake blank. The ethnographic and archaeological evidence presented here suggests that Late Archaic atlatl using groups of the Upper Trinity River would have employed 152-183 cm (5-6 ft.) long dart shafts that had detachable foreshafts. This would have economized breakage of the mainshaft and allowed for retrieval and recycling and was essentially a *K*-strategy projectile system. In that with the dart there were few projectiles or "offspring" carried or nurtured. The initial investment was higher in terms of raw materials, time, and labor and there was continued labor investment through the life cycle. It is likely their cost necessitated retrieval. Although some are rather delicate and intended to be a projectile, most would have a substantial chance of being recycled and reworked until they were exhausted and discarded. As with most *K* strategist animal species, these have a larger body size, which allowed for recycling potentials. This was a robust and curated projectile system.

On the other hand, arrows can be viewed as an *r*-strategy, in that many are carried and some are likely just extra raw shafts. And there is less investment in raw materials, manufacture time and labor. Their small size indicates that they are designed to be *expendable* and have a low probability of surviving a projection episode. There would be exceptions to these classifications just as there are in biology (Pianka 1970). Some arrows could be salvaged if not severely damaged and some of the dart points are rather delicate and exhibit no evidence of recycling. One could infer that there is a lower relative cost to the arrow, as they cost less to produce in materials, labor and time. This provided more flexibility and adaptability to the hunter in that they were not tethered to their projectile in the hunting process. The essence of hunting is being able to adapt to the contingencies of the pursuit, and an expendable, relatively low cost arrow, allowed hunters to pursue wounded game immediately after the shot, or alternately, they could pursue more encounters. The cost per shot was less with an attendant reduction in mobility restraints, before and after the shot. Thus, in the Upper Trinity River region it appears that they traded a multifunctional dart, which could often function as a knife, for a more versatile arrow. In terms of prey acquisition, it is possible that the impetus for the broad scale transition could lie as much in the fundamental differences in the ontogeny of the projectiles, as it does in the advantages of the bow in relation to the spearthrower. It is expected that these technological innovations represent increasingly efficient means to achieve the goals of population security.

One could logically surmise that the transition to the bow and arrow would increase success rates as Grayson and Cannon (1999: 146) state, "If technology changes return rates, or extraction efficiency must also change." The faunal remains associated with Late Prehistoric assemblages in the Upper Trinity support that claim as they indicate that there was an increase in the abundance of high ranked artiodactyls. This is in spite of the fact that the bow likely increased the ease of procurement for small game as well. Lower cost, expendable arrows used by adults and children likely increased the profitability of small animals of low caloric return. Both darts and arrows were used for killing large game, although the arrow by comparison was better suited to small game. Overall, it likely increased their ability to take all types of game. There is little doubt that the environment was an overriding factor in the relative abundance of artiodactyls in the assemblages during the Late Prehistoric period; however, the research presented here indicates that this was at least partly due to the bow and arrow. The bow was simply a more adaptable weapon that increased killing efficiency for large and small prey while the projectiles offered lower manufacturing costs and portability constraints.

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