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by

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The bow and arrow is a tool with a very long history. In the Old World its use dates back to paleolithic times, with firm evidence in the form of arrow shafts dated to the early ninth millennium b.c. (McEwen, Miller, & Bergman, 1991). More tenuous evidence from projectile points in Africa may push that back as far as 11000 b.c. (Blitz, 1988). The focus of this paper, however, will be the adoption and subsequent use of the bow in the Great Basin region of the West.

Given the long history of the bow in our world, it comes as no surprise to find that bows and bow use have generated their own vocabulary and terminology. In order to properly discuss these subjects, it is best to define a few of them.

All bows are typically described from the perspective of someone holding the bow ready to shoot. When held in this manner, the *Back* of the bow is the convex side or the side facing away. Conversely, the concave side or the side facing you is the *Belly*. The *Limbs* of a bow are its bending portions and are the parts of the bow lying between the *Nocks*, where the string is attached.

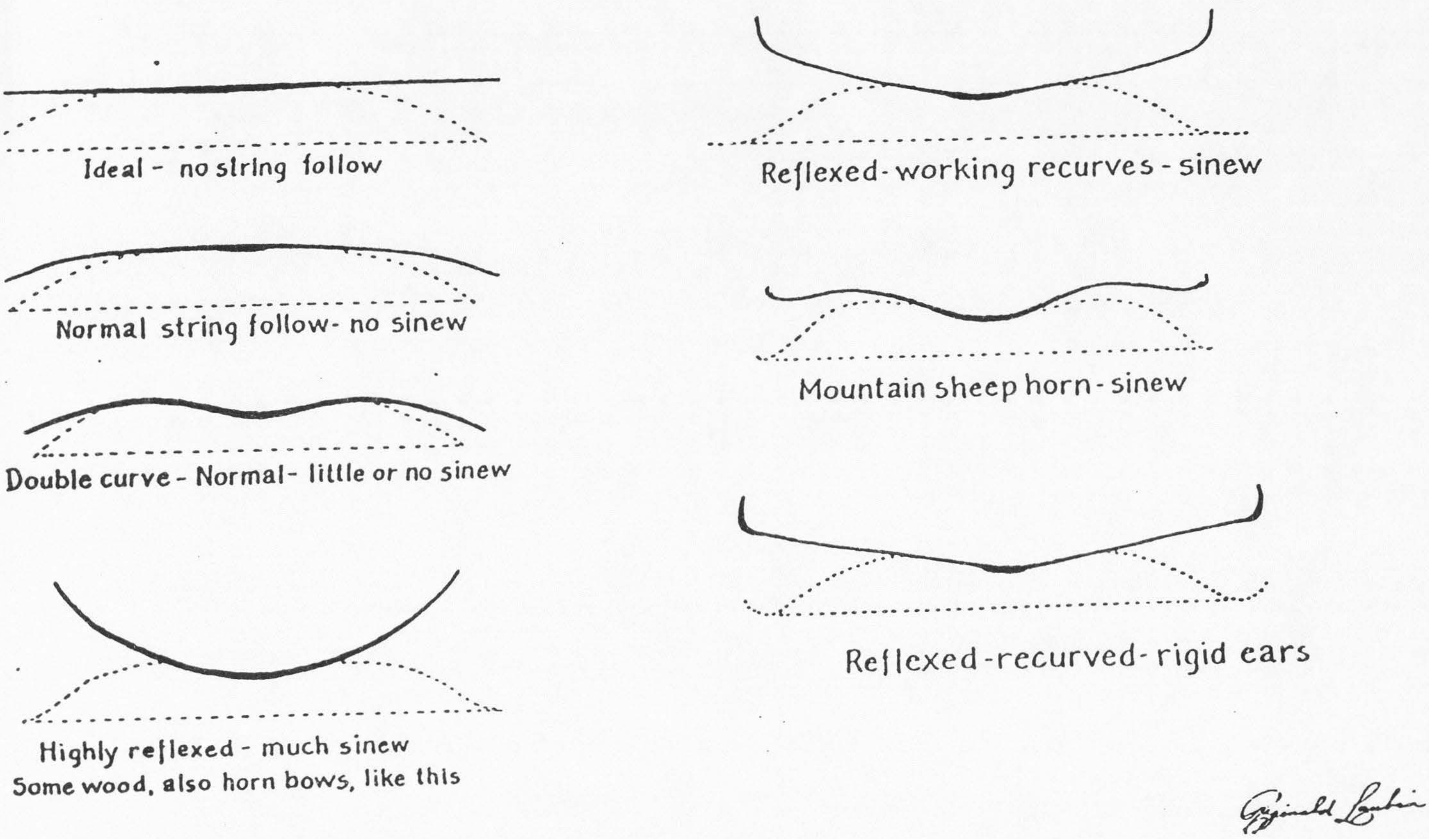
A working knowledge of some of the basic shapes and materials used in bow construction can also be of use. Bow shapes include the simple *D-shape*, which is the shape of the bow which we all tried to make as a kid, the *Double-curve*, which has limbs curving first toward the back of the bow and then toward the belly, and the *Reflexed*, where the bow limbs are set back from the grip to generate higher stress when the bow is brought to full draw. In addition, the ends of the bow limbs can be curved backwards beginning just below the nocks. This forces the string to contact the belly of the bow when it is *Braced*, i.e. strung and ready to shoot, and when it is done the bow is said to be *Recurved*. (See Figure 1 for examples of these.)

Materials used in construction vary, but wood is by far the most common. If a bow is constructed of a single piece of wood, it is said to be a *Self-bow*. If a thin layer of sinew is applied to the back of a bow, the bow is then called *Sinew-backed* or *Sinew-lined* (Hamilton, 1982). A *Composite bow* is one in which two or more material are used in its construction, typically horn and sinew.

All of the various shapes and materials defined above are chosen by the bowyer for certain reasons, and every possible design "represents one possible solution to the problem of hurling a small, light projectile with accuracy and penetrating power." (McEwen et al., 1991) To understand some of the factors influencing bow design, an elementary overview of bow physics is included here.

In essence, a bow is a two armed spring held under tension by a string. When the string is drawn back, the bow stave undergoes to opposing but complementary forces. The back of the bow is placed under enormous tensile stress as it is stretched, while the belly of the bow is simultaneously enduring severe

Figure 1. *



Bow shapes, relaxed and strung.

* Taken from:

Laubin, Reginald & Gladys Laubin (1980). American Indian Archery. Norman and London: University of Oklahoma Press.

compression. When the bow is fully drawn, potential energy is stored in the limbs and subsequently transferred to the arrow when the string is released.

The power of a bow results from its draw weight and its cast. The draw of a bow is the distance an arrow is pulled back from the grip. As a bow is drawn further, more stress (and hence more potential energy) is built up in the limbs and the arrow is released with greater force. The weight of a bow is a measurement of the amount of force necessary to draw an arrow a given distance. For two bows of equal draw length, the one with the higher draw weight will cast an arrow farther. Thus it is necessary to know both the draw of a bow and its associated weight before on can make an assessment of its power.

However, there is still the matter of cast. Even when two bows have the same draw weight, one will usually hurl an arrow farther. This is because one bow typically has a better cast; either it reacts much faster upon the arrow, more smoothly, or some combination of the two. A proper match of material with design, of curing with bow wood, and choice of limb length will all affect cast (Hamilton, 1982) and the potential draw weight.

After taking into account the limitations of the bow, the only other restrictions on the bow's performance are a product of the shooter's physical condition, size, and skill. A person's strength will limit the weight which he or she is able to draw, while anatomy controls the maximum length. In general, a person can draw an arrow no more than thirty inches or so (Pope, 1923).

At this point it is appropriate to talk about the classification of bows. In general, bows are classified in terms of the material used in their construction and fall into three broad categories: the self-bow, the reinforced or sinew-backed bow, and the composite bow.

The self-bow, as mentioned earlier, is made of a single piece of wood and relies solely upon the elasticity of the arms for its power (Hamilton, 1982). They are the simplest bow design, the earliest form of bow found, and considered the most common (Barnett, 1973), with D-curve bows more frequent than double-curved.

The best possible cross section for such a bow is trapezoidal, with the belly slightly wider than the back. Such a rectangular cross-section permits the greatest flexing of the bow limbs, and a bow can be built with shorter limbs and hence a sharper and flatter cast. In fact a bow with total arm length of twice the draw will give roughly optimal performance, but will also tax the limits of the wood. Such a design runs the risk of compression fractures in the belly or separation and splitting along the back. Consequently the length to draw ration will usually be somewhat less than this 2 to 1.

Of course these are all ideals of design, and in reality Native Americans products exhibit a considerable amount of variation. Reginald and Gladys Laubin (1980) even sketch an example of a Navaho bow which exhibits the one trait which Hamilton decries as the death of any bow: a round back. (A round back will concentrate all the stretching force along the thin center section of the back as the bow is bent, making it easy to split). Pope (1923), describes and provides a picture of a similar bow. Hamilton himself notices a change from the use of a rounded back in Pueblo I times, to the use of a flat back by Pueblo III. Every individual and group is trying to maximize their benefits in the face of constraints, and each is doing it in a different way.

The reinforced bow represents the next level of complexity in bow making. As a design, sinew-backed bows offer several advantages over the self-bow. Sinew is remarkably elastic, and when glued in thin sheets to the back of the bow both increases its strength and, after drying, gives the stave a reflex. A reflexed bow will automatically be under more stress when braced, and therefore have greater potential energy than a self-bow. The sinew gives added elasticity and strength, and prevents the back of the bow from splitting when drawn. Sinew backing thus allows a bow of equal draw weight to have shorter limbs and a sharper cast or greater draw weight. With these advantages, it is no wonder that the reinforced bow was popular throughout the Great Basin and North America.

If the sinew backing is such an advantage, one might ask why Indians didn't pack it on thick and really give bows some power. The answer lies in the belly of the bow. Remember that the back of a bow with a high reflex is already under tension when strung. Well, the belly of the same bow is under compression, and that compression increases when the bow is drawn. After a certain point, the ability of the sinew backing of the bow to survive tension exceeds the ability of the wooden belly to endure compression. The result is compression fractures and crushing of the wood cells, ruining the bow.

The answer to this is the composite bow. The final classification of bow, the composite design replaces the wooden belly of the bow with bone. The crushing strength of bow-woods range from 4200 psi for Rocky Mountain Juniper to 10800 psi for Black Locust. In contrast, elk horn has a crushing strength of 13000 to 15000 psi, including the porous center portions, and potentially twice that if one used only the outer parts.(Hamilton, 1982) By utilizing horn and sinew construction techniques for bows, it became possible to achieve the peak of performance. That Native Americans valued this form of bow over all others is widely documented. (cf. Steward, 1939; Kelly, 1964; Frison, 1980; Laubin & Laubin, 1980; Hamilton, 1982) In the New World, composite bows are also the most recent, with dates of ca. ad 1700 (Hamilton, 1982).

The construction of any of these types of bows varies considerably in terms of the amount of effort involved. Self-bows are far and away the simplest to construct, while the composite bow represents the greatest effort and time, involving anywhere from two weeks (Hamilton, 1982) to two months (Dominick, 1964).

The first step in the construction of a bow is the selection of material. The type of wood for self and reinforced bows was probably a matter of circumstance and environment (Dodge, 1883; Pope, 1923; Wilke, 1988), but it is becoming increasingly clear that the selection of the piece is not (cf. Wilke, 1988).

Pieces of wood of the proper size and shape were cut from the limb and/or trunks of trees. In his study of bow staves taken from juniper trees in western Nevada, Wilke notes the care taken to choose pieces which were free from knots, had proper grain characteristics, were relatively straight and free from lateral curvation, and of a suitable length. Theodora Kroeber (1961), describes Ishi's choice of juniper for a bow which he would use as "considered". (Ishi was the last Yahi Indian, who was brought to Berkeley by A.L. Kroeber early this century.) There is no reason to suspect that equal care wasn't taken by other Indians around the Great Basin and North America in their selection, except as possibly a matter of necessity.

After selecting the proper piece of wood, the next step was curing and shaping. Curing the wood could occur while leaving the piece on the tree (Wilke, 1988), somewhere warm and damp (Kroeber, 1961), in the sun for a week or a month (Fowler, 1989), or simply somewhere it could dry (Kelly, 1964). After this period, the bow was shaped. This process included roughing the bow out, tillering, and curving. (Tillering is the shaping the limbs so that every part does a proportionate share of the bending. It is the art which Hamilton claims distinguishes the expert bowyer from the amateur.) As cutting was undertaken, efforts were usually made to ensure that the heartwood of a limb formed the belly of a bow and sapwood the back.(Pope, 1923) This is because the heartwood was denser and more readily able to withstand compression, while the sapwood could better take the tension. Tillering along the back of a bow was done in such a way that cuts across the grain or age rings were avoided, since these would severely weaken the wood and lead to splitting. Curving the bow to introduce recurve or reflex (also a part of sinew backing) usually involved the application of heat to the bow (moist or dry), and then using heavy stones or pegs in the ground (Kelly, 1964) or your own body (Kroeber, 1961) to force the bow into a particular shape.

At this point, sinew backing was applied if desired. The sinew itself was usually dried to begin with, but was softened by wetting with water or chewing. Glue made from fish or animal hooves was boiled down and used to apply the sinew in a thin layer lengthwise along the stave. As it dried, the sinew would tighten and force the bow to become reflexed, giving the reinforced bow its strength and power. Sinew was also twisted to form the bow strings, and in some cases formed the nocks by being wound thickly around the top and bottom limb.

Horn bows follow a similar process of selecting the bone, splitting it, curing it (which usually meant softening it enough to become workable), cutting and shaping it, and fitting it together. The horn used in the Great Basin was typically elk or mountain sheep, while in the plains there are reports of the use of bison ribs. As mentioned previously, the horn formed the belly of the bow and sinew the back. Unlike reinforced bows, however, the sinew used in composite bows often made up to one-half the total thickness, leading them to be called sinew-back (not sinew-back*ed*) bows.

The size of bows varied a fair bit amongst various groups, but in the Basin generally ranged from three to four feet (Kelly, 1964; Fowler, 1986; Wilke, 1988). According to Hamilton (1982) and Kroeber (1961), the length of the bow was the distance from the fingertips of your left hand as it was held out perpendicular to the body down to the right hip joint. Kelly (1932) quotes informants among the Surprise Valley Paiute as saying they didn't measure for the length of a bow, they just knew. Still, its probable that there were certain criteria for fitting the length and width (grip) of a bow to the frame of the person wielding it.

One consistent point that has been brought out about the size of bows is that shorter bows are typically affiliated with horse riding peoples (Pope, 1923; Hamilton, 1982). While it is true that archery from horseback demands a shorter bow, it overlooks the fact that many peoples used bows of relatively short length even when they had no horses. This may be partly due to the superior cast of bows with short limbs, but is also very likely a function of available material. (Wilke, 1988) Juniper pieces, for example, are often not straight for any great length, and the horns of elk and mountain sheep are not very large.

The extent to which various Great Basin Native American groups (see Figure 2 for their distributions) have utilized the various design techniques listed above, as well as their choice of material, has been summarized in Table 1 and Table 2. (Lowie, 1909; Kelly, 1932; Steward, 1933; Kelly, 1964; McNitt, 1964; Frison, 1980; Thomas et al., 1986; Murphy & Murphy, 1986; Shimkin, 1986; Callaway et al., 1986; Kelly & Fowler, 1986; Zigmond, 1986; Liljeblad & Fowler, 1986; Fowler & Liljeblad, 1986; d'Azevedo, 1986; Fowler, 1989) The "X" in each box marks the presence of a particular design, style, or material. As can be seen, the sinew-backed bow seems to be the most frequently described, despite the assertion by Jorgensen (1980) that the self bow is the predominate bow type in the western United States. That this is the case may be more a product of the number and biases of the sources reviewed than of an error on Jorgensen's part. Most ethnographers either are not or were not archery aficionados, nor was archery tackle necessarily of primary concern. That they would know enough to differentiate between recurved and double-curved, or readily assess that a weapon was reflexed (very difficult to tell, unless the weapon is seen unstrung) is not particularly surprising. Even museum curators are infamous for leaving bows standing on end, strung, or even strung backwards. Gathering a larger, more broadly based sample from this region would certainly be helpful in

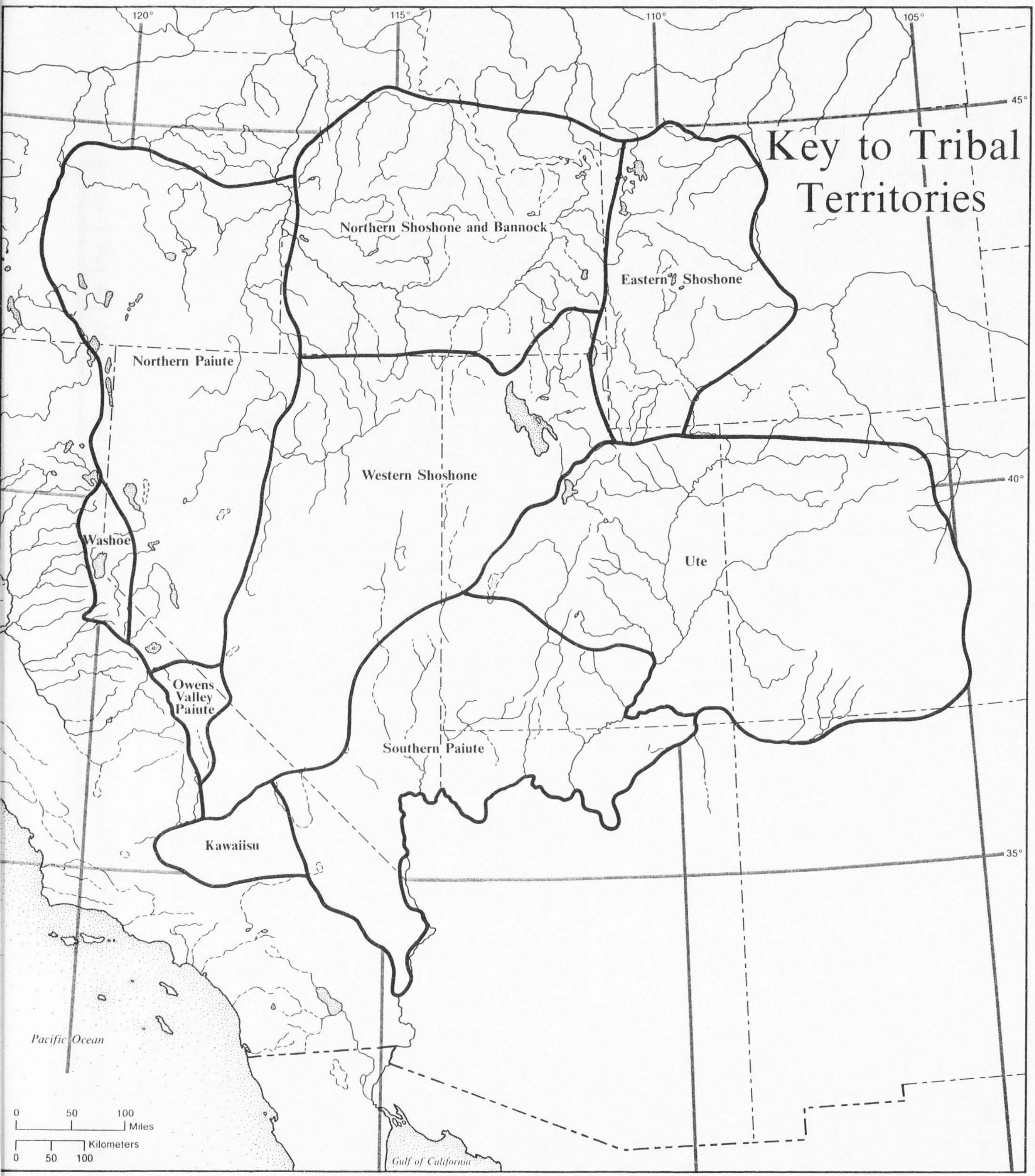


Figure 2. *

* Taken from:

d'Azevedo, Warren L. (Ed.) (1986a). Handbook of North American Indians, vol. 11: The Great Basin. Washington: The Smithsonian Institution.

Table 1. Bow Design Element Distributions

	Self	Sinew-Backed	Horn	D-Curve	Double-Curve
Anasazi				X	
Navajo		X			
Washoe	X	X		X	
Ute	X	X		X	X
Northern Shoshone	X	X	X	X	X
Eastern Shoshone		X			
Western Shoshone		X			
Northern Paiute	X	X	X *		
Southern Paiute, General	X	X	X	X	X
Kaibab Paiute			X		
Kawaiisu Paiute		X			
Owens Valley Paiute		X			
Panguitch Paiute		X			
San Juan Paiute		X	X		X
Surprise Valley Paiute	X	X			

* The Northern Paiute of western Nevada did not use horn bows (Fowler, 1989).

Notes: 1. Northern Shoshone includes the Bannock tribe.
2. The information for the Southern Paiute, General comes from Isabel Kelly's Southern Paiute Ethnography.

Table 2. Bow Material Distributions

	A	B	C	D	E	F	G	H	I	J	K	L	M
Anasazi													
Navajo													
Washoe													
Ute		X	X			X			X				X
Northern Shoshone	X							X				X	X
Eastern Shoshone													
Western Shoshone			X										
Northern Paiute	X		X										
Southern Paiute, General			X	X			X		X				X
Kaibab Paiute													
Kawaiisu Paiute			X										
Owens Valley Paiute			X							X	X		
Panguitch Paiute			X		X		X		X				
San Juan Paiute							X						X
Surprise Valley Paiute			X				X						

A - Cedar
B - Chokecherry
C - Juniper
D - Locust
E - Mtn. Birch
F - Mtn. Mahogany
G - Oak
H - Pine
I - Serviceberry
J - Water Birch
K - Willow
L - Elk Horn
M - Mtn. Sheep Horn

determining the nature of any biases in design reporting, as well as in material type. As can be seen, the material used by some groups was never mentioned.

In order to see how this information about bow use might be fruitfully applied, let us look at a small self-bow. This bow was found during a field school near Mt. Irish Nevada (100 miles N/NE of Las Vegas) during the summer of 1992, and is described as follows:

The Mt. Irish bow is a self-bow of juniper wood measuring 104 centimeters from tip to tip and 120.5 centimeters along the belly (approximately 3 1/2 feet). The end of the limbs have been treated with heat and bent back to give them recurve, and the limbs themselves show a slight reflex. However, there is no sign of sinew application anywhere on the bow, nor is there any evidence of nocks (though it appears they might have been broken off). The back of the bow is flat and rough, partly from weathering, while the belly is rounded and much smoother. Rodent gnawing has damaged the stave over almost 45 centimeters of its length, mostly near the center. One of the bow limbs is bleached white from exposure to the elements, being the end projecting out from the crevasse in which the bow was found. Finally, the last few centimeters of each tip are smoothed very evenly, and may be the product of metal tool use.

What can be gleaned from this information? First of all, the size and construction of the bow is consistent with Wilke's reported average for staves of this material found in western Nevada. The location of the find places it in an area historically known to be occupied by the Southern Paiutes, and a brief glance at Table 2 will show that juniper was indeed a popular choice of wood. This information, coupled with the fact that the ends may have been worked with metal tools, leads one to speculate that the bow is indeed a fairly recent product of some member of the Southern Paiute people.

However, without further information this must remain speculation! The bow was not found in context with any other artifacts; something which could have possibly helped establish some sort of association. Furthermore, whether the ends were smoothed using metal tools remains to be seen. Possibly some sort of experimental replication with metal and stone tools will highlight the differences enough for some assessment to be made. That the bow was made of juniper also loses significance when one realizes that juniper was used more widely than any other material. Finally, the construction of the bow is straightforward and consistent with a wide variety of Basin populations (although it appears that the bowyer used the sapwood of the tree for the belly of the bow and the heartwood for the back (which was either very rough or unfinished), something which is rather unusual.) All of this is not meant to say that nothing useful has been determined, but that it must be taken with a grain of salt and that more work needs to be done.

There are hints in the ethnographic literature that a more detailed analysis of bow morphology could be potentially very enlightening. Dodge (1883) makes the following observation,

> "However apparently alike, the bows and arrows of each tribe differ so materially from those of other tribes, that an Indian, and even some frontiersmen, will, from a glance at either, say to what tribe it belongs."

There are many accounts of Indians painting their bows or arrows, or otherwise marking them in some way. (cf. Lowie, 1909; Kelly, 1932; Kelly, 1964; Fowler, 1989; Laubin & Laubin, 1980; Hamilton, 1982) Whether this was deliberately done to differentiate between groups is questionable. Kelly (1932) mentions that among the Surprise Valley Paiute, "Identification of one's arrow was important because it affected the division of spoils." The result of this might well be the distinction mentioned by Dodge, but the purpose remains quite different. Only by looking at various bow staves and arrows in some depth, including design, material, and also now the decoration, could we generate data that bear meaningfully on this question.

Another area of potential research is the functional relationship, if any, between the bow, arrow, and projectile point. There has long been interest in determining at what stage a projectile point ceases to belong to a spear and instead becomes an arrow point (Blitz, 1988), and articles exist that seek to address this problem (i.e. Thomas, 1978). However, while Hamilton (1982) does a nice job of pointing out the balance between material, draw, and weight in bow design, there has yet to be any systematic review or testing of all three components of the weapon.

The bow and arrow is a tradition with a long history in the Great Basin, in the Americas, and in the world. From that tradition a whole vocabulary dealing with the bow has developed, one which allows us to converse competently about various aspects of bow design, construction, and use. After looking at only a small portion of the ethnographic literature we see how an understanding of the interactions of all these things might allow us to place an isolated find, the Mt. Irish bow, into some kind of cultural context. Even more important, we see how much more research can and needs to be done. A more detailed analysis of various aspects of bows already in the possession of museums, along with some experimental archaeology on bow construction, could lead to great insights concerning the functional relationships of various design aspects of bow, arrow, and projectile point, as well as information regarding the use of stylistic variation to identify cultural affiliation. And while these goals are probably the easiest to achieve, they also provide a springboard for more processual questions concerning reasons for adoption (cf. Blitz, 1988) and variation in design and construction.

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