DART AND ARROW POINTS ON THE COLUMBIA PLATEAU OF WESTERN NORTH AMERICA

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The timing of the bow and arrow's introduction, spread, and replacement of the atlatl is an important research question in North American prehistory. Although regional archaeologists have not focused on the issue, it is generally thought that the bow and arrow were introduced on the Columbia Plateau ca. 2,300 years ago and completely replaced the atlatl by 1000 B.P. We apply two sets of discriminate functions and four threshold values to three large projectile point samples from the Columbia Plateau and a control sample from the Western Great Basin. Our results indicate that the atlatl was used on the Plateau by ca. 10,800 B.P. While the bow and arrow may have been present by 8500 B.P., they were ubiquitous in the region by 4400 B.P. Atlatl use appears to have increased for a while after 3000 B.P. At the same time, metric differences between dart and arrow points strengthened. Darts became rare after 1500 B.P. but seem to have been in use in small numbers at least until contact.

El momento de introducción y dispersión del arco y flecha así como su reemplazo por el atlatl constituyen importantes temas de investigación de la prehistoria de Norte América. Aunque los arqueólogos regionales no se han concentrado en este tema, en general se piensa que el arco y flecha fueron introducidos en la meseta de Columbia hace unos 2,300 años y que reemplazaron completamente al atlatl hacia 1000 a.P. En este trabajo aplicamos dos conjuntos de funciones discriminantes, cuatro valores de umbral y patrones de variación por tamaño a lo largo de tres dimensiones métricas a tres grandes muestras de puntas de proyectil de la meseta de Columbia y a una muestra de control de la Gran Cuenca occidental. Nuestros resultados indican que el atlatl fue utilizado en la meseta desde ca. 10,800 a.P. Asimismo, el arco y flecha pudieron ya estar presentes para el 8500 a.P. y ya eran ubicuos en la región hacia el 4400 a.P., aunque sin reemplazar completamente al atlatl. El uso del atlatl parece haberse incrementado por un tiempo con posterioridad a 3000 a.P. Al mismo tiempo las diferencias métricas entre puntas de dardo y puntas de flecha se hicieron más notables. Los dardos se tornaron raros después del 1500 a.P., pero parecen haber continuado en uso hasta tiempos del contacto. En suma, no se trata de una historia de reemplazo directo de un arma por otra, sino que ambos sistemas de armas estuvieron en uso al mismo tiempo durante varios milenios en la meseta de Columbia.

When and how the bow and arrow were introduced, spread, and replaced the atlatl are important research questions in North American prehistory. In the Pacific Northwest the accepted date for this is within the last 2,300 years, with the two weapon systems used together for several centuries. The bow is thought to have completely replaced the atlatl ca. 1000 B.P. (e.g., Chatters 2004). This same sequence is believed to hold for much of western North America. The bow's introduction is sometimes used to explain a documented increase in warfare after A.D. 500 (e.g., Chatters 2004; Lambert 2002; Maschner 1991). However, Webster (1978, 1980) and Chance and Chance (1982) place the introduction of the bow and arrow in the northern Great Basin and Columbia Plateau as early as ca. 3500 B.P. The evidence supporting their suggestions is weak.

The bow and arrow may have been introduced in the central and eastern United States ca. 4000–3000 B.P., with spatially and temporally patchy use until they became the region's sole projectile system by 1000 B.P. (Nassaney and Pyle 1999). In Newfoundland, at North America's northeastern corner, the two weapon systems may have been used together after the bow and arrow arrived

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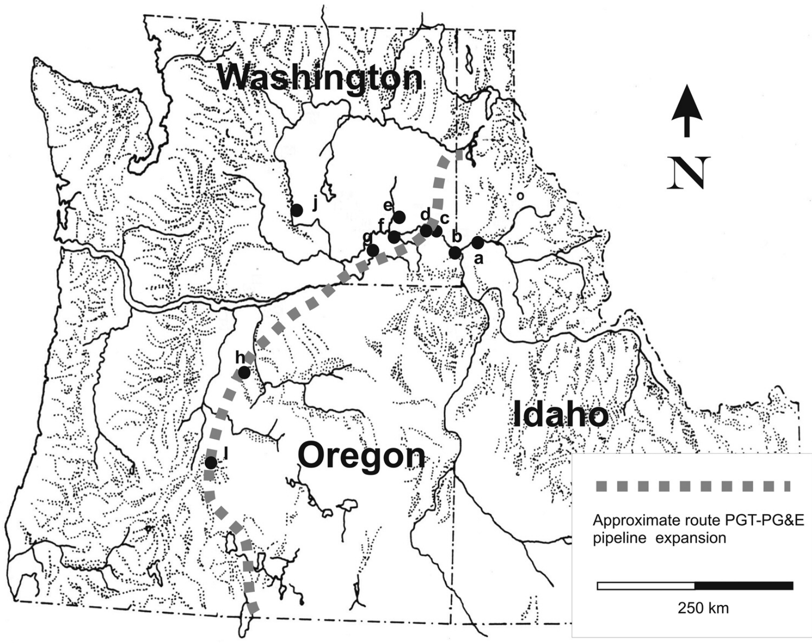

Figure 1 Sites discussed in this paper. A. Hatwai, B. Alpowai, C. Granite Point, D. Wawawai, E. Marmes, F. Tucannon, G. Windust Caves, H. 35JE51B, I. 35DS557, J. Ryegrass Coulee. The dashed line is the approximate route of the PGT – PG&E Pipeline Expansion Project.

there around 1000 B.P. (Erwin et al. 2005). In the West, the bow and arrow apparently were present in the Great Basin by 2000 B.P. (Yohe 1998), replacing the atlatl ca. 1350 B.P. (e.g., Bettinger and Eerkins 1999). With some exceptions—notably, Corliss's (1972) pioneering study on neck widths—there has been scant interest in this issue among archaeologists working in the Intermontane Plateau of western North America. In contrast to the immediately adjacent Great Basin and other areas, and despite early interest (e.g., Smith 1954), archaeologists on the Plateau have been little concerned with projectile point variation and classification (Pettigrew et al. 1995; but see Andrefsky 2004; Carlson and Magne 2008; Lohse 1985). Where regional researchers have addressed the bow and arrow's introduction, they have used neck widths to separate darts from arrows (e.g., Ames 2000; Chatters et al. 1995).

We present evidence indicating that the history of these two projectile technologies on the Columbia Plateau differs markedly from the generally accepted picture. Using the multiple data sets and lines of evidence discussed below, we argue that the atlatl was present on the Columbia Plateau at 10,800 B.P. and that while the bow and arrow may have been introduced as early as 8500 B.P, they were in wide use by 4400 B.P. Both weapon systems were subsequently used together over several millennia. After 3000 B.P. dart and arrow points became increasingly differentiated in size. The atlatl then became a minor component in the hunting tool kit but remained in use after 1000 B.P.

We use measurements from four large projectile point data sets: 859 points from the Western Great Basin (WGB), 271 points recovered at the Hatwai (10NP143) site in west-central Idaho, 713 points from the Lower Snake River (LSR) region of the eastern Columbia Plateau, and 613 points collected during a major pipeline project in central and northeastern Oregon (Figure 1). The WGB points serve as a control sample. Our empirical results are based on the Hatwai, LSR, and "Pipeline" samples. We first present the four data sets and then explain the methods we used, describe our results, discuss them, and conclude.

Data Sets

Western Great Basin

The 859 Western Great Basin projectile points include reported points from Gatecliff Rockshelter (Thomas 1983) and currently unreported points from the Alta Toquima site and the Jefferson Plateau area (Thomas 2008). Temporally, they span the middle and late Holocene. Typologically, they include representatives of most of the major projectile point types in the WGB (Table 1). They provide a well-known and understood control sample against which to compare the three Plateau data sets. Use of this control sample is helpful because formal variation is much better controlled and typological methods are more fully and explicitly developed in the Great Basin than on the Plateau. Thomas (1981) stresses that his typological methods were developed to create historically sensitive types, not functional types. However, they seem to measure functional change across time. We applied the equations and thresholds described below to Thomas's data in "dry runs" to learn how they worked and to ensure that our results are consistent with those of other researchers.

Hatwai

Hatwai (10NP143) is located on the Clearwater River 11 km upstream of the Clearwater's confluence with the Snake River at Lewiston, Idaho, and Clarkston, Washington. The site was excavated in 1977 and 1978 as an extensive test excavation prior to expansion of U.S. Highway 94 to four lanes (Ames et al. 1981). The site is now capped by the highway's westbound lanes. The excavations recovered 271 projectile points classified into 14 types (Table 1). They span the period from ca. 10,800 B.P. to 2800 B.P. (Ames et al. 1981; Sanders 1982) and are assignable to four temporal components at the site. Point measurements used Thomas's (1981) system for measuring Great Basin projectile points.

Hatwai I, the site's earliest occupation, is a component of the Windust phase, the earliest well-documented cultural manifestation on the Plateau (Ames 1988, 2000), although there are scattered finds of Clovis or Western Fluted points (e.g., Reid et al. 2008) and Haskett material (Galm and Gough 2008) in the region. The Windust phase is generally dated between 10,800 and 8500 B.P. (Leonhardy and Rice 1970) by a large suite of radiocarbon dates (Ames 2000; Huckleberry and Fadem 2007; Sheppard et al. 1987). Hatwai I is dated between ca. 10,800 and 9800 B.P., a date range commensurate with the early portion of the Windust phase.[1] Windust projectile points are stemmed lanceolate points (Rice 1972; Sanders 1982) and are the Plateau variant of the Western Stemmed Point complex (Ames 1988). Windust points are metrically and formally variable (Rice 1972), partially as a result of extensive repair and reworking of the points during their use life. Excavations at Hatwai recovered 21 Windust points and point fragments (Figure 2). Measurements from 11 complete and nearly complete specimens are used here.

The Hatwai I assemblage was recovered from the surface of and within a late Pleistocene/early Holocene gravel bar. Two composite radiocarbon samples date the base of the exposed deposits (TX3158 and TX3159; Table 2). These dates are statistically identical, producing a pooled average of 10,796 ± 138 B.P. The dated stratum yielded three stemmed points (Figure 2). A composite charcoal sample from a facies of the gravel bar exposed in an excavation unit located 120 m east produced a date of 10,110 ± 720 B.P. (Table 2). No cultural materials were associated with this dated sample. These three dates are statistically identical, with a pooled mean of 10,741 ± 171 B.P., suggesting that the bar predates 10,000 B.P. The gravel deposits grade upward into silt/sand alluvium (QAE [Cochran 1988]). This deposit above the gravels has two dated samples: 8800 ± 1310 (TX3265) and 9160 ± 230 (TX3086). These are statistically the same, with a pooled mean of 9149 ± 227 B.P. This date is supported by six dates elsewhere in the site (Table 2; Cochran 1988). These six dates are also statistically identical, having a pooled mean of 9229 ± 97 B.P. Given all of this, a terminal date of 9800 B.P. for the gravel bar is reasonable. While the cultural deposit is a lag deposit, the recovered artifacts show little or no abrasion, water rolling, or other evidence of water movement. A refitting study provides additional evidence for the integrity of this gravel surface assemblage. Sanders (1982) was able to refit flakes to cores with flakes recovered within a meter of the core. The assemblage is clearly a palimpsest representing multiple light occupations by mid-latitude foragers (Ames 1988).

The small Hatwai II assemblage was recovered from the upper QAE and middle Holocene alluvium (QAM) that unconformably overlies the QAE. The unconformity contains a wedge of fan gravels with volcanic ash identified as Mazama ash

Table 1. Means and Standard Deviations for Measurements Used in This Study for the Western Great Basin and Hatwai Projectile Point Types.

				Width		Weight		Thickness		Neck Width	
	N	Age Span (Years B.P.)		Mean	sd	Mean	sd	Mean	sd	Mean	sd
WGB point types											
Concave Base	18	4700–4500		19.5	5.2	3.6	2.8	5.0	1.1		
Cottonwood Triangular	108	650–contact		12.4	2.5	.7	.3	3.1	2.4		
Desert Sidenotched	189	650–contact		12.6	1.8	.6	.2	2.6	.5	6.0	1.3
Elko Corner-notched	284	3000–1300		23.2	3.4	3.7	1.6	5.0	4.7	11.4	2.3
Elko Eared	95	3000–1300		23.6	4.8	4.5	5.8	5.3	5.6	13.7	5.4
Gatecliff Contracting Stem	33	4500–3000		20.7	4.8	3.5	1.5	4.7	1.0	9.5	2.6
Gatecliff Split Stem	34	4500–3000		23.7	6.4	3.6	1.4	5.0	.9	12.0	2.5
Humboldt series	13	4500–1200		22.7	3.4	4.4	1.2	5.5	.4		
Large Side Notched	6	?–650		22.7	1.7	4.4	1.2	5.5	.4	13.1	2.1
Rosegate Series	97	1300-650		17.8	3.0	1.7	.7	3.3	.6	7.1	1.0
Hatwai Point Types											
Desert Side Notch	4	500	150	13.7	3.8	.3	.1	2.8	.1	6.8	1.5
Columbia Stem A	5	2800	150	17.3	.6	1.0	.2	3.6	.9	5.9	1.4
Small Side Notch	4	3400	3000	13.3	1.3	1.4	.4	4.5	.6	8.5	1.3
Columbia Corner Notch A	32	4000	2000	17.0	3.0	2.4	.8	5.4	1.3	9.4	1.4
Quelomene Bar C Notch	24	4000	2000	18.1	3.5	2.5	2.0	5.2	1.3	10.0	1.1
Rabbit Island Stem A	14	4000	2000	14.4	3.4	2.4	2.9	4.9	1.2	8.0	2.4
Medium Corner Notch	7	4000	2000	17.3	2.1	1.7	.5	4.4	.5	10.4	1.2
Misc. Corner Notch	11	4000	2000	15.0	2.0	2.0	1.0	5.3	.8	9.7	2.6
Foliate	9	4400	2800	15.1	2.6	3.5	.5	5.8	.5		
Hatwai-Eared	119	4400	2800	14.2	3.3	3.0	4.5	5.4	1.1	9.9	1.3
Hatwai-Eared A	114			13.7	1.9	2.2	1.9	5.2	.9	9.9	1.2
Hatwai-Eared B	5			17.6	18.0	14.9	10.2	7.6	2.7	12.2	2.9
Nespelem Bar	13	4400	3000	17.8	5.4	6.9	7.9	6.2	1.1	10.8	1.7
Cold Springs	1	7000	3200	18		4		8		12	
Cascade	13	8500	4500	15.0	2.0	3.2	1.3	5.3	1.0		
Windust	11	10800	9800	19.5	3.8	5.8	2.8	6.2	1.0	13.6	2.2

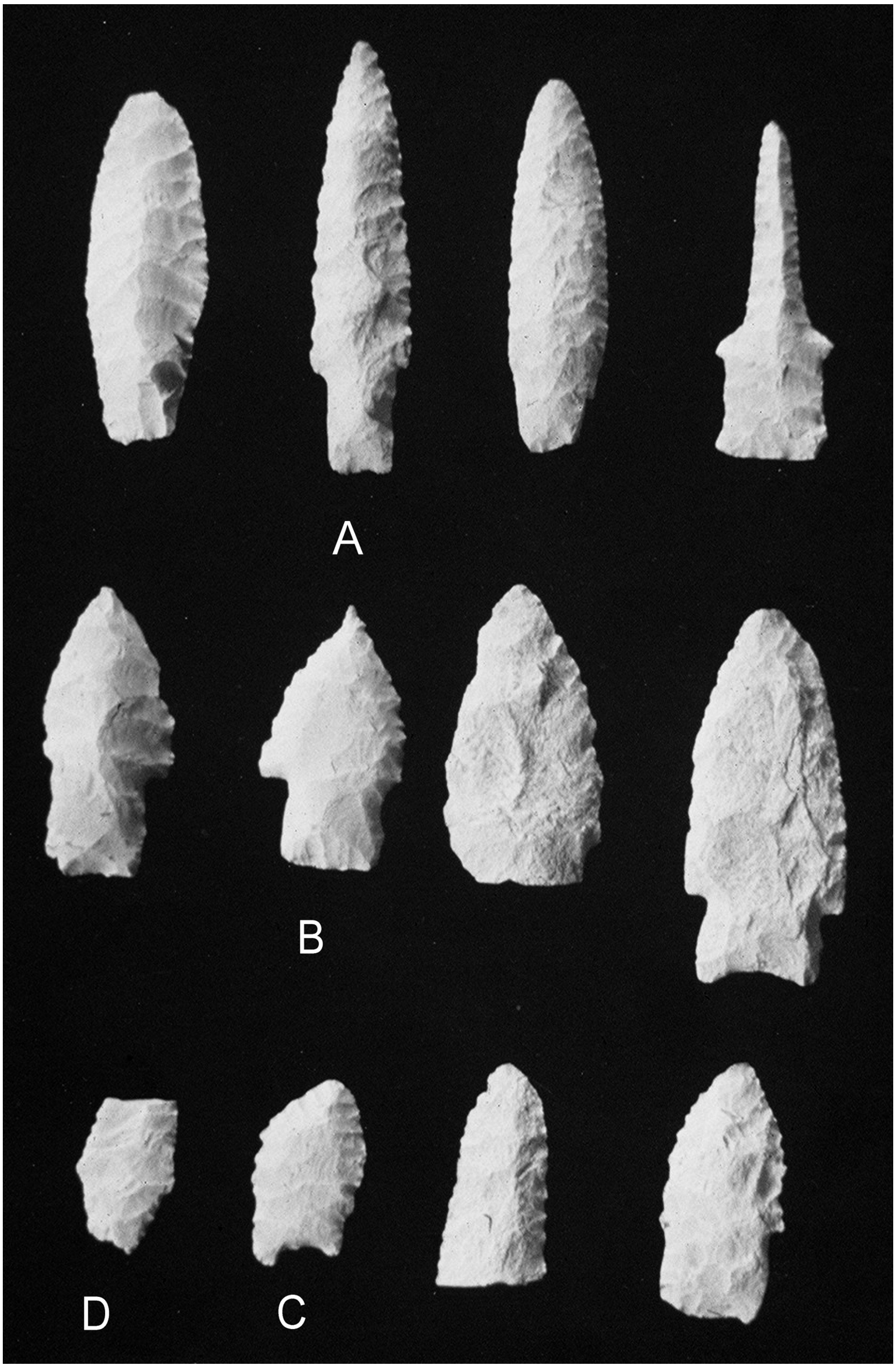

Figure 2. Hatwai Windust points. A is a complete point. It is 71 mm long, 16mm wide, with a neck width of 10 mm and a basal of 11 mm. C and D are arrow size. B exemplifies reshaping and size reduction of Windust points. B and C were recovered in the basal stratum dated c 10,800 BP (see text).

Table 2. Dates Discussed in the Text.

Lab. No.	Site/Component	Context	Date	2σ Calibration B.P. (p)
Mean	All Hatwai IIIB dates		3267±40	3393–3581 (1)
WSU1878	Hatwai IIIB	House 1 Fill	3130±70	3158–3484 (.99)
WSU1829	Hatwai IIIB	House 2 Fill	3240±90	3319–3689 (.97)
WSU1842	Hatwai IIIB	House 1 Fill	3330±70	3396–3720 (.99)
TX3092	Hatwai IIIB	House 2 Fill	3420±380	2778–4647 (.99)
TX3264	Hatwai IIIB	House 2 Fill	3440±100	3455– 3929 (.99)
TX3088	Hatwai IIIA	House 2 Floor	4120 ±110	4380–4871 (.98)
Mean	TX 3933, 5721, 5720, 3263		4441±75	4869–5290 (1)
Mean	TX 5721, 5720, 3263		4406±75	4806–5290 (.94)
TX3263	Hatwai IIIA	House 1 Floor	4340±90	4806 5290 (.94)
TX5720	Hatwai IIIA	House 1 Floor	4470±190	4783–5587 (.93)
TX5721	Hatwai IIIA	House 1 Floor	4740±230	4850–5930 (1)
TX3933	Hatwai IIIA	House 6 Floor	5050±320	5026–6841 (.99)
TX3262†	Hatwai IIIA	House 1 Floor	5550±220	5892–6862 (.99)
TX3085	Hatwai IIIA	QAM	4310±70	4789–5056 (.86)
TX3161	Hatwai II	QAM	5450±120	5983–6468 (.98)
TX3983	Hatwai II	QAM	5780±130	6308–6863 (.99)
WSU1828	Hatwai II	QAM	6165±150	6719–7336 (.96)
TX3084	Hatwai II	QAM	6240±100	6895–7333 (.97)
TX3982	Hatwai II	QAM	6260±160	6779–7463 (.99)
Beta53621	35JE51B	Pre-Mazama	6670±60	7435–7622 (.99)
Beta57179	35JE51B	Pre-Mazama	7035±65	7711 –7970 (1)
MEAN	TX QAE dates		9229±97	10,226–10,503 (.97)
WSU1840	Hatwai II	QAE	7860±90	8509–8989 (.97)
TX3082	Hatwai II	QAE	8560±520	8372–10,833 (.98)
TX3266	Hatwai II	QAE	8660±1660	6171- 13,859 (.99)
TX3265	Hatwai II	QAE	8800±1310	7166–13,238 (1)
TX3086	Hatwai II	QAE	9160±230	9664–10,882 (.95)
TX3083*	Hatwai II	QAE	9280±110	10,230–10,737 (1.0)
TX3081	Hatwai II	QAE	9320±1830	6438 - 15,307 (1.0
WSU2440*†	Hatwai II	QAE	9880±110	11,086 - 11,770 (.99)
MEAN	TX 3160, 3158, 3159		10741±171	12,230-13,041 (.98)
TX3160	HATWAI I	GRAVELS	10110±720	9736–13,295 (1)
MEAN	TX 3158, 3159		10796±138	12,556–13,050 (.92)
TX3158	HATWAI I	GRAVELS	9850±870	9120-13,361 (.99)
TX3159	HATWAI I	GRAVELS	10820±140	12,570–13,081 (.95)

All dates are on charcoal. Calibrations were performed with CALIB 5.0.1 (Stuiver et al 1995) for this paper. Sources: Hatwai Ames et al. 1981, TX5720, 5721 not previously reported. 36JE51B (Pettigrew and Hodges 2005).
* Dates from the same sample
† Dates judged to be too early

(Cochran 1988), pyroclastic materials from the eruption that produced Crater Lake in the Cascade Mountains of southern Oregon. The multiple eruptions are dated between 6700 and 7000 B.P. (e.g., Bacon 1983). The QAM is also dated by five radiocarbon dates (Table 2) that firmly place it between 6200 and 5500 B.P. The occupation was very light. Archaeological materials were covered in bedding planes in the silty QAE and QAM;[2] no features were recognized. This is typical of Cascade phase occupations, which probably represent very mobile foragers (Ames 1988). Artifacts were also recovered in mixed deposits beneath and between Hatwai III pithouses that were excavated through the QAM and QAE to the underlying gravels. On typological grounds, Hatwai II is a component of the early Cascade subphase of the regional sequence's Cascade phase (Leonhardy and Rice 1970), which dates between 8500 and 7000 B.P. (Bense 1972). The Hatwai II radiocarbon dates indicate that the assemblage may contain late Cascade subphase materials. It does include Cascade points (Figure 3), the diagnostic projectile point style of the entire Cascade phase. Cascade points are small, bifacial,

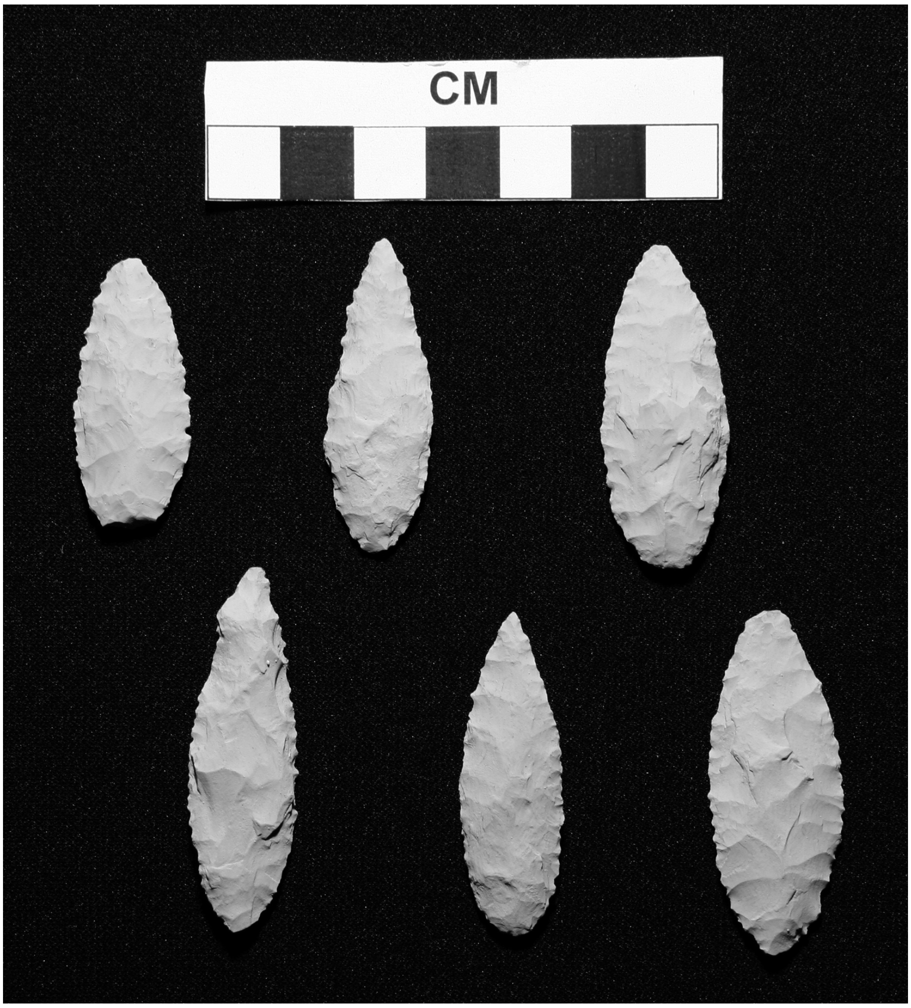

Figure 3. Hatwai Cascade points.

foliate lanceolate points. The 13 Hatwai Cascade points fit the formal and technological definitions of the type (Bense 1972; Butler 1961; Leonhardy 1970; Nelson 1969; Ozbun and Fagan 2006). Assemblages of this period contain other foliate and occasional stemmed points. The Hatwai Cascade assemblage does not include the large side- and corner-notched points (Northern/Cold Springs Side Notched) that, with Cascade points, are among the diagnostic artifacts for the late Cascade subphase (7000–4500 B.P. [Bense 1972]). Only three of these points were recovered at Hatwai, and they are part of the Hatwai III assemblage.

Hatwai III is the largest Hatwai occupation. It is dated by 11 radiocarbon dates (Table 2). These indicate two major occupational episodes: Hatwai IIIA between 4400 and 4000 B.P. and Hatwai IIIB between 3500 and 3100 B.P. Other evidence suggests that the recovered occupation may extend as late as 2800 B.P. Hatwai IIIA contained at least five semisubterranean pithouses, three of which are radiometrically dated. Three of the dates from the floor of House 1 and the single date from the lowest floor of House 6 (Table 2) are statistically the same. Their pooled mean of 4441 ± 75 B.P. provides an initial date for Hatwai III. The 5500 B.P. date from the House 1 floor is considered too early. The Hatwai IIIA houses were filled with silty alluvium after 3500 B.P. or so and were completely invisible by 3000 B.P., with houses built over them.

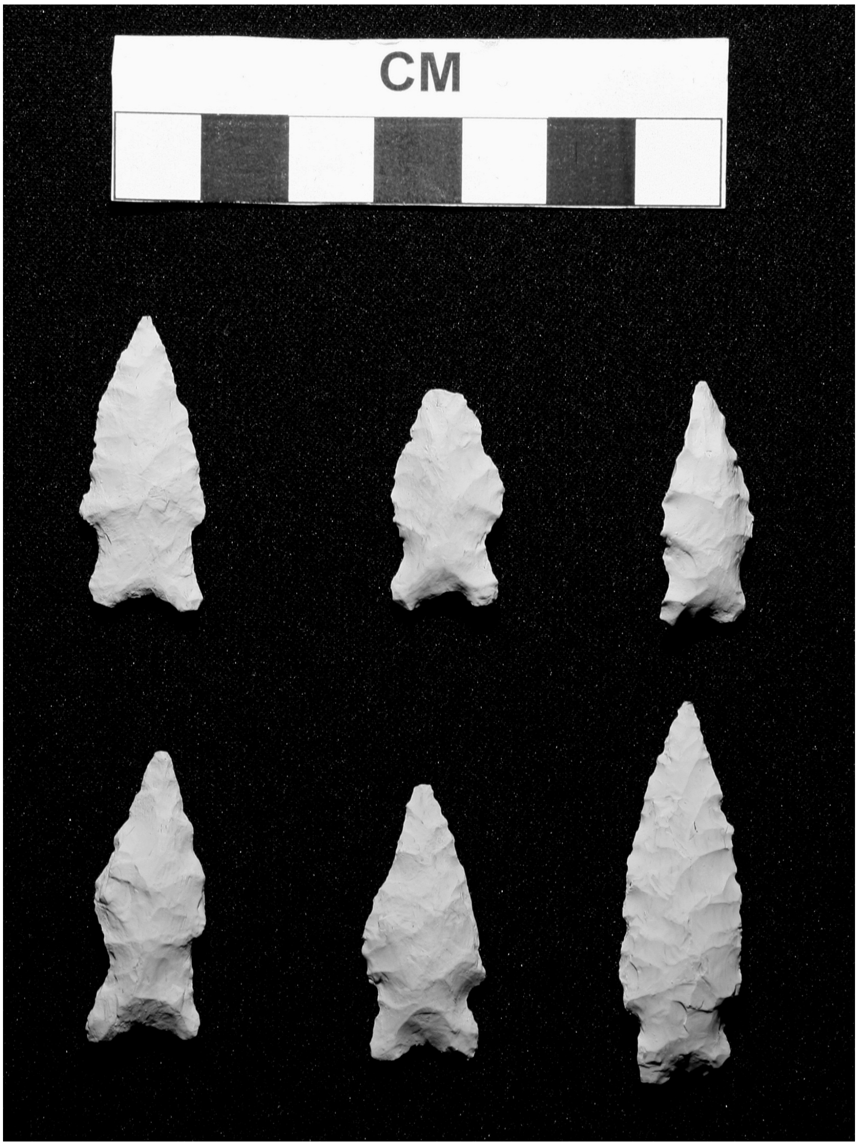

Figure 4. Hatwai Hatwai Eared points.

Hatwai IIIB is contained in this alluvium. It includes at least three houses and extensive activity areas probably associated with dwellings that were destroyed or capped by the original highway construction. Assemblage distinctions between these two contexts are not relevant to this discussion, and they are treated here as one.

The 237 Hatwai III projectile points are here assigned to 11 projectile point classes, most of which are variants of Plateau-wide projectile point types (Lohse 1985; Lohse and Shou 2008; Pettigrew et al. 1995). The most common type, however, is the Hatwai Eared point (Ames 1984; Figure 4), which is not among Lohse's (1985; Lohse and Shou 2008) standardized western Plateau point styles. It occurs in sites in the Lewiston Basin (Brauner 1976), just west of Hatwai, and upstream along the Clearwater River and on the adjacent uplands (Ames 1984). Brauner (1976) suggested that the point is a variant of Elko Eared points of the Great Basin. This research began as a test of that suggestion. Hatwai Eared points are metrically more similar to WGB Rosegate points

Table 3. Comparison of the Means of Metric Attributes and Ratios of Elko Eared Gatecliff Split Stem, Rosegate and Hatwai Eared Points. Attributes and Ratios Based on Thomas 1981.

Attribute	Elko Eared	Gatecliff SS	Rosegate	Hatwai Eared
Maximum Length mm	39.9	40.2	30.8	29.0
Maximum Width mm	23.6	23.7	17.8	14.2
Basal Width mm	18.2	11.8	8.1	11.4
Neck Width mm	13.7	12	7.1	9.9
Thickness mm	5.3	5	3.3	5.4
DSA	165.4	183.8	137	214
PSA	132.0	91.9	110.9	111.0
Weight gm	4.5	3.6	1.7	3.0
Basal Width:Neck Width	1.3	1	1.1	1.1
Basal Width:Maximum Width	.8	.5	.5	.5

than to Elko Eared points (Thomas 1981; Table 3).[3] Although they are smaller, they also have some strong similarities to WGB Gatecliff Split Stemmed points (e.g., Zeanah and Elston 2001:Figure 2a–b, e–h), with which they are contemporary. Thus Brauner was correct in his basic inference that the point style has strong affinities with some middle and late Holocene Great Basin point types. They are also similar to Pettigrew et al.'s (1995) definition of Cold Springs Side Notched points. An analogous style seems to be associated with the Shuswap Horizon of the central Canadian Plateau's culture history. The Shuswap Horizon dates to ca. 3500–2400 B.P. (Rousseau 2008). The Hatwai Eared points are found throughout the Hatwai III deposits and are directly associated with the House 1 and House 6 radiocarbon dates discussed above.

Hatwai IV materials are from scattered contexts postdating 2800 B.P. that survived the site's use as a source of fine materials by the Idaho Highway Department. We estimated that perhaps >50 cm of deposit were lost when the site was periodically stripped by belly loaders. Isolated pockets of intact deposits survived.

Lower Snake River Region

The LSR data include reported means of projectile point types spanning the 11,000-year sequence of the Lower Snake River region of eastern Washington (Figures 1 and 5). The LSR is the run of the Snake River from its confluence with the Clearwater River to its confluence with the Columbia River (Figure 1). During the 1960s and 1970s, Washington State University and University of Idaho archaeologists conducted salvage excavations of sites in the proposed reservoirs of dams under construction along the Snake River. The Marmes Rockshelter excavations are the best known of these (Hicks 2004; Rice 1969). The series of excavations were the framework for an 11,000-year-long cultural-historical sequence (Leonhardy and Rice 1970; Figure 5), the longest on the Intermontane Plateau.

The LSR is the logical comparative data set for Hatwai, since it is clearly part of that region (Sappington 1994) and was excavated using techniques developed in the LSR. We culled projectile point measurements from the final reports and from the syntheses presented in Ph.D. dissertations and M.A. theses (Figure 5). Virtually all of these studies were completed by people supervised and trained by Frank Leonhardy of Washington State University and the University of Idaho and so were quite standardized in descriptive format. Ames was also trained by Leonhardy and so is very familiar with the methods employed.

This standardization of analytical and descriptive procedures has strengths and weaknesses. Mean measurements are reported for artifact type, not on individual specimens. Means and either standard deviations or minima and maxima are reported, rarely both and sometimes only minima and maxima. Measurements were not consistently recorded. For example, Rice (1972) did not record weights for his classes of Windust points. When assemblages are described, projectile points and other artifacts are grouped into phase, site, and even component-specific typologies rather than standardized, regional ones. While some regional types are employed (e.g., Windust, Cascade, Cold Springs Side Notched), usually they are not or they are referred to only in passing. This is typical of

Years BP	Hatwai	Lower Snake River Phase	Sites	Sources
150		Nimipu	Wawawai	Yent 1976
500		Late	Wawawai	Yent 1976
1000		Harder		
1500		Early	Alpowa Locality	Brauner 1976
2000		Harder		
2500			Alpowa Locality	Brauner 1976
3000		Tucannon	Tucannon	
3500			Granite Point	Kennedy 1976
4000	Hatwai		Wawawai	
4500				
5000		Late Cascade	Granite Point	Leonhardy 1970
5500			Alpowa Locality	Brauner 1976
6000				
6500				
7000	Early	Early	Granite Point	Leonhardy 1970
7500	Cascade	Cascade	Alpowa Locality	Brauner 1976
8000				
8500				
9000			Granite Point	
9500		Windust	Marmes	Rice 1972
10000	Windust		Windust Caves	
10500				
11000				

Figure 5. Hatwai Lower Snake River Cultural Chronology and sources used in this study for projectile point measurements by phase. Years are radiocarbon years BP.

Plateau projectile point typologies (Ames 2000; Pettigrew et al. 1995). Where the reports assigned points to regional types, we employ them. Otherwise, we use the study-specific types since we could not reliably combine them. This strategy probably inflates typological diversity, particularly for later periods. However, it is generally not a serious problem for our purposes.

PGT-PG&E Pipeline Project

The last data set comes from a pipeline project (Pipeline) across central Oregon. Between 1988 and 1993, INFOTEC Research Inc. and its subcontractors conducted a range of archaeological services, including survey and data recovery, for the Pacific Gas Transmission Company and the Pacific Gas and Electric Company on a pipeline route that included central Oregon and southeastern Washington (Figure 1). Southern portions of the route in Oregon are variously considered parts of the Great Basin or the Columbia Plateau. However, much of the route was within the southern Columbia Plateau (Moratto et al. 1994).

The project recovered 855 projectile points. Of these, 613 could be classed into 20 projectile point types, some of which were regional types and others that were project specific. Analysts did, however, develop project-level and regional-level projectile point types that they explicitly defined using an approach deriving from Thomas's Great Basin key (Pettigrew et al. 1995; Thomas 1981). Therefore, the types are replicable. The project archaeologists also reported measurements on individual points. The point types defined and used in this project span the full known sequence for the southern Columbia Plateau, from the Windust phase to the arrival of the horse, ca. A.D. 1720.

Methods

To distinguish dart from arrow points we employ two sets of discriminate functions, four threshold values, and patterns of size variation along three metric dimensions (Table 4, Figure 6). The discriminate functions are Shott's (1997) revisions of Thomas's (1978) for darts and arrows—specifically, his single-variable classification function using shoulder width. Thomas measured 132 stone-tipped arrows and 10 darts in ethnographic and archaeological collections of the American

Table 4. Hughes's (1997) Threshold Values.

Attribute	Thrusting Spear	Flight spear	Unfletched dart	Fletched dart	Bow & arrow
Weight (gm)	227	0–156	9–70	3–8	0–11
Tip sectional area (cm^2)	3.1	2.1	.67	.67	.47
Perimeter (cm)	10.48	8.2	4.8	4.8	4.0

Museum of Natural History. Of the arrows, 118 were ethnographic specimens from across North America and 14 were archaeological specimens from Pueblo Bonito that were clearly arrows. The 10 darts were archaeological specimens hafted on foreshafts that were directly and "indisputably" associated with atlatls (Thomas 1978:468). Thomas (1978) recorded length, width, thickness, neck width, and weight on projectile points and diameter and length on foreshafts. With these measurements, he explored a classification equation to distinguish darts from arrows. The resulting equation misclassified three of 10 dart points (30 percent) as arrows and 17 of 128 arrow points (14 percent) as dart points. Shott (1997) added 29 darts to Thomas's original sample, measuring specimens at 11 museums. Most of these are archaeological artifacts from the Southwest. He took four measurements: length, shoulder width, neck width, and (maximum) thickness. In his analysis, Shott tested discriminate functions with four variables (length, shoulder width, neck width, and thickness), three variables (shoulder width, neck width, and thickness), two variables (shoulder width and thickness), and one variable (shoulder width). He concluded that shoulder width was the most useful discriminating variable in his samples. Applied to Thomas's arrow sample, it correctly identifies 89 percent. In another study, Bradbury (1997) also employed discriminate functions to distinguish arrows from darts but used neck width and maximum width.

With this in mind we tested Shott's (1997) four-variable functions against the Hatwai samples and the two-variable functions against the Hatwai and Lower Snake River samples. Since the two-variable functions obtained results identical to the single-variable function results, we felt justified in using the single-variable classification function. This allowed us to employ the largest possible point samples. We were able to include broken points that lack the landmarks required for some measurements as well as points without attributes that are sometimes diagnostic. These latter point types include foliate Cascade points, which by definition are unstemmed and therefore cannot be measured for neck width. When applicable, we also used Bradbury's (1997) two-variable discriminate functions, which employ width and neck width. We did

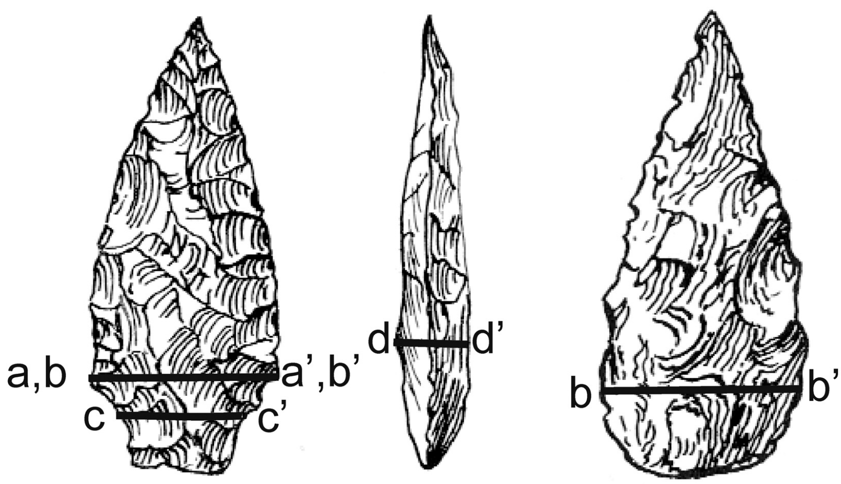

Figure 6. Measurements on Hatwai Points used here: a-a' shoulder width, b-b' maximum width, c – c' neck width, d – d' maximum thickness. Shoulder width and maximum width were recorded separately.

so—despite Shott's (1997) findings that neck width is unreliable in separating arrow and dart points—because neck width has been used to distinguish dart points from arrow points on the Columbia Plateau (e.g., Ames 2000; Chatters et al. 1995; Corliss 1972; Fawcell 1998), and Nassaney and Pyle (1999) found it a useful threshold value in their central Arkansas sample.

Shott's (1997) single-variable functions are

$$\text{dart: } 1.40(\text{shoulder width}) - 16.85$$
$$\text{arrow: } .89(\text{shoulder width}) - 7.22$$

The point is classified according to the larger result. Bradbury's (1997) two-variable functions are

$$\text{dart: } (1.420838 \times \text{width}) + (.05398166 \times \text{neck width}) - 17.31622$$
$$\text{arrow: } (.6320802 \times \text{width}) + (.5082722 \times \text{neck width}) - 7.86771$$

As with Shott's function, the projectile is classified according to the larger result.

In addition to the discriminate functions we used four threshold values to distinguish arrow points from dart points. Three of the threshold values are Hughes's (1998): weight, tip sectional area, and perimeter (Table 4). Hughes's formulas for tip sectional area and perimeter are

$$\textit{Tip area} = \tfrac{1}{2}\,\text{thickness} \times \text{width}$$
$$\textit{Perimeter} = 4s, \text{ where } s = (\tfrac{1}{2}\,\text{width})^2 + (\tfrac{1}{2}\,\text{thickness})^2$$

To develop her values, Hughes reviewed the engineering requirements for dart and arrow performance as well as the utility of a range of measurements, examining how point morphology reflects the functional demands of the two projectile systems. She concluded that mass (weight), tip cross section or sectional area, and tip perimeter are the best threshold values for separating arrow points and dart points. Tip sectional area (or "cross section") is based on the maximum thickness and maximum width of the point. It is a measure of how pointed the tip of the projectile is. Tip perimeter uses thickness and maximum width to calculate the size of the shaft to which the point was affixed. It is therefore a proxy measure for shaft diameter, which cannot be larger than the arming point because the missile would otherwise have difficulty penetrating its target. Hughes applied these three measurements to a sample of 391 points from Mummy Cave in Wyoming and concluded that the bow and arrow were introduced in Wyoming sometime after 2000 B.P. and had completely replaced the atlatl by 1300 B.P. She also noticed a change in atlatl technology at around 7900 B.P.; dart points after this date are smaller and more uniform in size than earlier ones. She explains this as a consequence of fletched dart shafts replacing unfletched shafts.

Our fourth threshold is neck width. Although several neck width thresholds have been proposed (Beck 1995; Chatters et al. 1995; Nassaney and Pyle 1999), we selected 10 mm. Points with neck widths less than 10 mm were classified as arrows; those with neck widths greater than 10 mm were classed as darts. We have neck width measurements for the Hatwai and WGB data sets. The median neck width for Hatwai points is 10 mm, and the median WGB neck width is 10.95 mm. Hatwai neck widths have a normal, unimodal distribution, while the WGB neck widths are weakly bimodal, with the modes separated at 10 mm (Figure 7). Our neck width threshold correctly classifies 55 percent of Thomas's arrow points and 90 percent of his dart points.

These various values and formulas are not entirely independent of each other. Hughes's perimeter and tip sectional areas are both calculated using maximum width and thickness but use different formulas. Additionally, neither is completely independent of Thomas–Shott's or Bradbury's discriminate functions because they all use shoulder or maximum width: Hughes's equations employ thickness, and Bradbury uses neck width. Width is the crucial measurement. In our calculations, Hughes's tip area alone correctly classifies 93 percent of Thomas's arrows and 73 percent of the Thomas–Shott darts. Perimeter correctly classifies 92 percent of the arrows and 80 percent of the darts. Weight correctly classes 89 percent of Thomas's arrow sample and 60 percent of the darts. These are probably optimum results because Hughes used the Thomas–Shott data, among others, in developing and testing her thresholds. In applying her thresholds to the Mummy Cave samples, Hughes found that her archaeological points tended to be smaller than her thresholds predicted.

Given the importance of width measurements, it should be noted that there is some apparent variation among these researchers either in the width measurements they use or in how they label them.

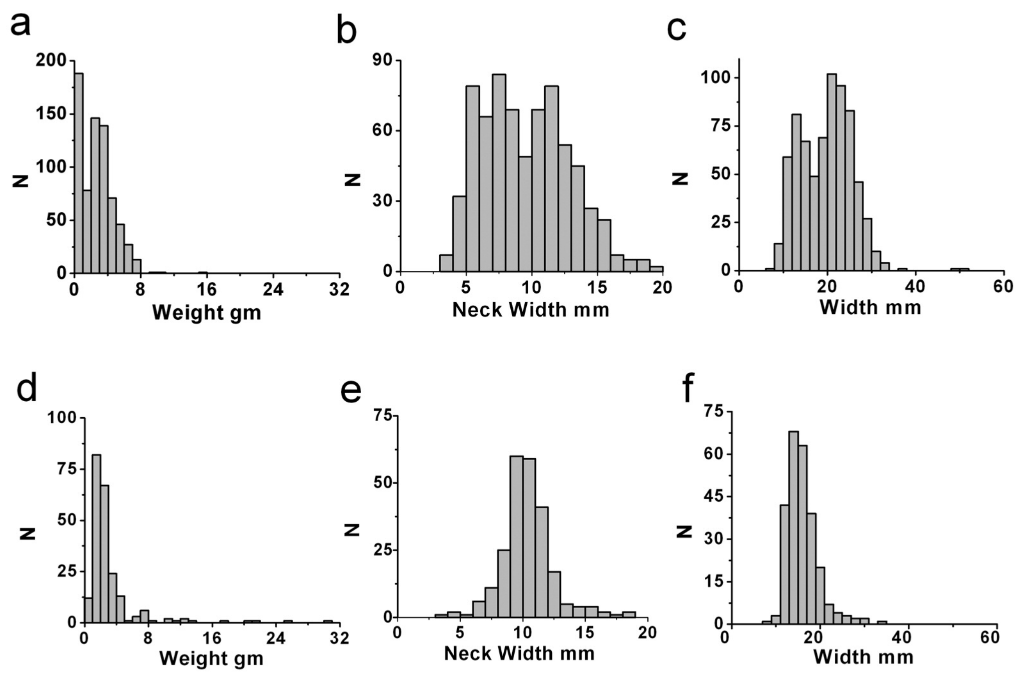

Figure 7. Comparisons of Western Great Basin and Hatwai projectile point sizes by weight (panels a, d) neck width (b, e) and width (c, f).

Hughes (1998:Figure 7) clearly distinguishes maximum from shoulder width in her measurements and uses maximum width in her formulas. The other investigators do not clearly distinguish the two. Thomas (1978) uses width but does not specify whether he measured maximum or shoulder width. Elsewhere (e.g., 1984) he reports the maximum width for each point, so we assume that he measured maximum width on the museum specimens. Shott (1997) assumes that Thomas's width is shoulder width. In his text and graphs Shott discusses shoulder width, but in his Table 1 the measurement is labeled maximum width. Bradbury (1997) also uses width without specifying maximum or shoulder width. On the Hatwai artifacts, we recorded a range of measurements, including maximum width, shoulder width, neck width, and maximum thickness (Figure 6). In many of the Hatwai stemmed/notched points, shoulder width is the maximum width, as it no doubt is in the collections Bradbury, Shott, and Thomas examined. In our calculations, we use maximum widths for forms both with and without shoulders.

Our results for the WGB and Hatwai points are presented in a series of tables (Tables 5–10). The tables include the means and standard deviations for the measurements we use for each WGB and Hatwai projectile point type (Table 1). Classification of the WGB and Hatwai point types as either arrows or darts is displayed at two levels: by actual artifact count and by the type means for each measurement (Tables 5 and 7). Thus Table 5, for example, shows that of the 284 Elko Eared points in the WGB sample, 240 are classed as darts and 44 as arrows by the Thomas–Shott equation, 246 as darts and 12 as arrows by Bradbury's equation, and so on. It also shows that the Elko Eared projectile point type is classed as a dart by the Thomas–Shott equation using the type's mean maximum width. Despite injunctions against employing means (e.g., Bradbury 1997), we calculated them to assess their utility for distinguishing darts and arrows because the Lower Snake River data are exclusively mean values. To more easily evaluate the classification results of the various equations and thresholds for each projectile point type, the counts in Tables 5 and 7 were converted to percentages (Tables 6 and 8). These percentages are further reduced in these tables to a single index: the "cumulative percentage." The cumulative percentage summarizes the

Table 5. Great Basin Projectile Points Dart/Arrow Assignments: Totals of Points/Type Assigned as Darts/Arrows Based on Different Classification Equations and Thresholds. Points are Assigned as Either Arrows or Darts, Intermediate Sizes (Large Arrow/Small Dart) are Assigned as Darts.

		Thomas-Shott		Bradbury		Weight		Neck Width		Tip area		Perimeter	
Point Type	N	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow
Cottonwood	108	1	107				108				108		108
Mean			X				X				.2		1.8
Desert SN	189	1	188		189		189		189		189		189
Mean			X		X		X		X		.16		1.7
Elko CN	284	240	44	246	12	198	85	206	78	186	91	222	61
Mean		X		X		X		X		.6		5.6	
Elko Eared	95	77	18	76	7	73	22	73	22	63	24	74	20
Mean		X		X		X		X		.73		5.8	
Gatecliff CS	33	21	12	27	6	18	15	11	22	17	16	20	13
Mean		X		X		X			X	.5		4.7	
Gatecliff SS	34	29	5	30	2	23	11	27	7	23	10	27	7
Mean		X		X		X		X		.57		6.1	
Humboldt	13	4	9			9	4			4	9	4	9
Mean			X			X				.46	.46		3.3
LSN	31	26	5	5		5	1	5	1	6		6	
Mean		X		X		X		X		.62		5.5	
Rosegate	97	37	60	29	68	5	92		97	1	96	28	69
Mean			X		X		X		X		.3		3.3

Table 6. Great Basin Projectile Point Assignments: Percentage of Points/Type Assigned as Darts/Arrows Based on Different Classification Equations and Thresholds. The Cumulative Score Is the Sum of the Actual Percentages Divided by the Possible Total Percentage.

	Thomas-Shott		Bradbury		Weight		Neck Width		Tip area		Perimeter		Cumulative	
Point Type	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow
Cottonwood	.9	99.1				100.0				100.0		100.0	.2	99.8
Desert SN	.5	99.5		100.0		100.0				100.0		100.0	.1	99.9
Elko CN	84.5	15.5	95.3	4.7	70.0	30.0	72.5	27.5	67.1	32.9	78.4	21.6	78.0	22.0
Elko Eared	81.1	18.9	91.6	8.4	76.8	23.2	76.8	23.2	72.4	27.6	78.7	21.3	79.6	20.4
Gatecliff CS	63.6	36.4	81.8	18.2	54.5	45.5	33.3	66.7	51.5	48.5	60.6	39.4	57.6	42.4
Gatecliff SS	85.3	14.7	93.8	6.3	67.6	32.4	79.4	20.6	69.7	30.3	79.4	20.6	79.2	20.8
Humboldt	30.8	69.2			69.2	30.8			30.8	69.2	30.8	69.2	40.4	59.6
LSN	100.0		100.0		83.3	16.7	83.3	16.7	100.0		100.0		94.4	5.6
Rosegate	38.1	61.9	29.9	70.1	5.2	94.8		100.0	1.0	99.0	28.9	71.1	17.2	82.8

Table 7. Hatwai Projectile Points: Dart/Arrow assignments: Totals of Points/Type Assigned as Darts/Arrows Based on Different Classification Equations and Thresholds. Points Are Assigned as Either Arrows or Darts, Intermediate Sizes (Large Arrow/Small Dart) are Assigned as Darts.

		Thomas-Shott		Bradbury		Weight		Neck Width		Tip area		Perimeter	
Point Type	N	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow
Windust	11	5	6	5	6	10	1	10		9	2	5	6
Mean			X		X	X		X		.65		4.3	
Cascade	13		13			7	6			3	10		13
Mean			X			X					.43		2.8
Columbia CN B	32	7	25	12	16	7	25	9	23		32	3	29
Mean			X		X		X		9.4		.19		2.5
Columbia S A	5		5	3	2		5		5		5		5
Mean			X	X			X		5.9		.09		2.5
Desert SN	4		4	1	3		4		4		5		5
Mean			X		X		X		6.8		.07		1.1
Foliate	9	1	8			8	1				9	1	8
Mean			X			X					.22		2.6
Hatwai Eared	119	7	112	9	101	10	65	37	75	2	109	4	111
Mean			X		X		X		9.9		.17		2.1
Nespelem Bar	13	3	10	7	8	7	6	7	6		13	3	10
Mean			X		X	X		10.7			2.6		3.1
Quelomene Bar CN	21	7	14	7	14	3	22	9	13	1	21	8	13
Mean			X	X			X		10		.22		3.3
Rabbit Island S	14	1	13	3	11	2	12	1	11		12	1	11
Mean			X		X		X		8		.18		2.3
Hatwai Small SN	4		4		4		4		4		4		4
Mean			X		X		X		8.5		1.5		2
Hatwai Medium CN	7	2	5	1	6		7	5	2		7	1	6
Mean			X		X		X	10.4			.19		3.2
Hatwai Misc. CN	11	1	10	1	11	2	8	4	7		10	1	10
Mean			X		x		X		9.7		.18		2.5

Table 8. Hatwai Projectile Points. Percentage of Points/Type Assigned as Darts/Arrows Based on Different Classification Equations and Thresholds. The Cumulative Score Is the Sum of The Actual Percentages Divided by the Possible Total Percentage.

	Thomas-Shott		Bradbury		Weight		Neck Width		Tip area		Perimeter		Cumulative	
Point Type	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow	Dart	Arrow
Windust	45.5	54.5	45.5	54.5	90.9	9.1	100.0		80.0	20.0	54.5	45.5	69.4	30.6
Cascade		100.0			53.8	46.2			23.1	76.9		100.0	19.2	80.8
Columbia CN B	21.9	78.1	42.9	57.1	21.9	78.1	28.1	71.9		100.0	9.4	90.6	20.7	79.3
Columbia ST A		100.0	60.0	40.0		100.0		100.0		100.0		100.0	10.0	90.0
Desert SN		100.0	25.0	75.0		100.0		100.0		100.0		100.0	4.2	95.8
Foliate	11.1	88.9			88.9	11.1				100.0	11.1	88.9	27.8	72.2
Hatwai Eared	5.9	94.1	8.2	91.8	13.3	86.7	33.0	67.0	1.8	98.2	3.5	96.5	11.0	89.0
Nespelem Bar	23.1	76.9	46.7	53.3	53.8	46.2	53.8	46.2		100.0	23.1	76.9	33.4	66.6
Quelomene Bar	33.3	66.7	33.3	66.7	12.0	88.0	40.9	59.1	4.5	95.5	38.1	61.9	27.0	73.0
Rabbit Island	7.1	92.9	21.4	78.6	14.3	85.7	8.3	91.7		100.0	8.3	91.7	9.9	90.1
Hatwai Small SN		100.0		100.0		100.0		100.0		100.0		100.0		100.0
Hatwai Med CN	28.6	71.4	14.3	85.7		100.0	71.4	28.6		100.0	14.3	85.7	21.4	78.6
Misc. CN	9.1	90.9	8.3	91.7	20.0	80.0	36.4	63.6		100.0	9.1	90.9	13.8	86.2

Table 9. Lower Snake River Projectile Points by Period. Types Are The Number of Projectile Types/Period, Mean Is The Mean Number of Points/Type. Points Are Assigned as Either Arrows or Darts, Intermediate Sizes (Large Arrow/Small Dart) Are Assigned as Darts.

Phase	N	Arrow	Dart	% Arrow	% Dart	Types	Mean
Nimipu	39	34	5	87.2	12.8	12	3.25
Late Harder	146	123	23	84.2	15.8	31	4.71
Early Harder	125	73	52	58.4	41.6	26	4.81
Tucannon	160	136	24	85.0	15.0	25	6.40
Late Cascade	31	19	12	61.3	38.7	10	3.10
Early Cascade	85	83	2	97.6	2.4	4	21.25
Windust	203	39	181	19.2	89.2	18	11.28

Table 10. Classification of Projectile Points from the Pipeline Project.

Point Type	Mean	N	N Arrow	N Dart	% Arrow	% Dart	Time Range
Lanceolate Concave Base	Dart	6	3	3	50.0	50.0	10,500–7500 B.P.
Cascade	Arrow	16	12	4	75.0	25.0	8000–3500 B.P.
General Willow Leaf	Dart	19	9	10	47.4	52.6	8000–3500 B.P.
Mahkin Shouldered	Dart	32	11	21	34.4	65.6	8000–3500 B.P.
Cold Springs SN A	Arrow	8	6	2	75.0	25.0	7000–3500 B.P
Cold Springs SN B	Arrow	22	17	5	77.3	22.7	7000–3500 B.P.?
Shaniko Shouldered	Arrow	79	46	33	58.2	41.8	5000–1000 B.P.
John Day Barbed	Arrow	21	10	11	47.6	52.4	4000–1500 B.P.
John Day Shouldered	Arrow	31	24	7	77.4	22.6	4000–1500 B.P.
Rabbit Island Stemmed	Arrow	42	35	7	83.3	16.7	4000–1500 B.P.
Shaniko Barbed	Arrow	75	44	31	58.7	41.3	3000–150 B.P.
Madras Barbed	Dart	8		8		100.0	post-3000 B.P.
Madras Shouldered	Dart	19	3	16	15.8	84.2	post-3000 B.P.
Quilomene Bar BN	Dart	21		21		100.0	post-3000 B.P.
Madras SN	Dart	4		4		100.0	post-3000 B.P.
Willowdale Square Barbed	Arrow	14	12	2	85.7	14.3	2200–1600 B.P.
Miller Island Diamond Stem	Arrow	8	8		100.0		post 2000 B.P.
Sherman Pin Stem	Arrow	36	34	1	94.4	2.8	1750–115 B.P.
Plateau Corner-Notched	Arrow	116	112	4	96.6	3.4	1500 B.P.- Protohistoric
Plateau Side-Notched	Arrow	5	4	1	80.0	20.0	1500 B.P.- Protohistoric

information for each projectile point type by summing the percentages for darts or arrows across the tables' columns and dividing by the theoretical sum (400 for points without neck widths, 600 for those with). For example, the cumulative percentages for the museum arrow and dart samples are as follows: darts, 81 percent (cumulative percentage of darts correctly identified by all measures); arrows, 85 percent (cumulative percentage of arrows correctly identified by all measures). Because of differences in available data, the LSR and Pipeline results are displayed differently: only the Thomas–Shott results are presented since the relevant reports did not include point weight or thickness.

Finally, we used patterns of variation in weight, tip area, and perimeter in order to distinguish arrow and dart points (Figure 8). The patterns for arrow (Figure 8a) and dart (Figure 8b) points are displayed in three-dimensional graphs, in which the weights (x-axis), tip areas (y-axis), and perimeters (z-axis) of Thomas and Shott's museum samples are plotted. In Figure 8c, tip area and perimeter only are plotted because Shott did not record the weights of the darts that he added to Thomas's sample. Individual artifacts are circles: open circles are points classed as darts by the Thomas–Shott formulas; gray circles are classed as arrows. In these graphs, as in Figure 8a, arrows tend to cluster tightly in the lower right segment of the graph space, while darts are higher and more dispersed in the space (Figure

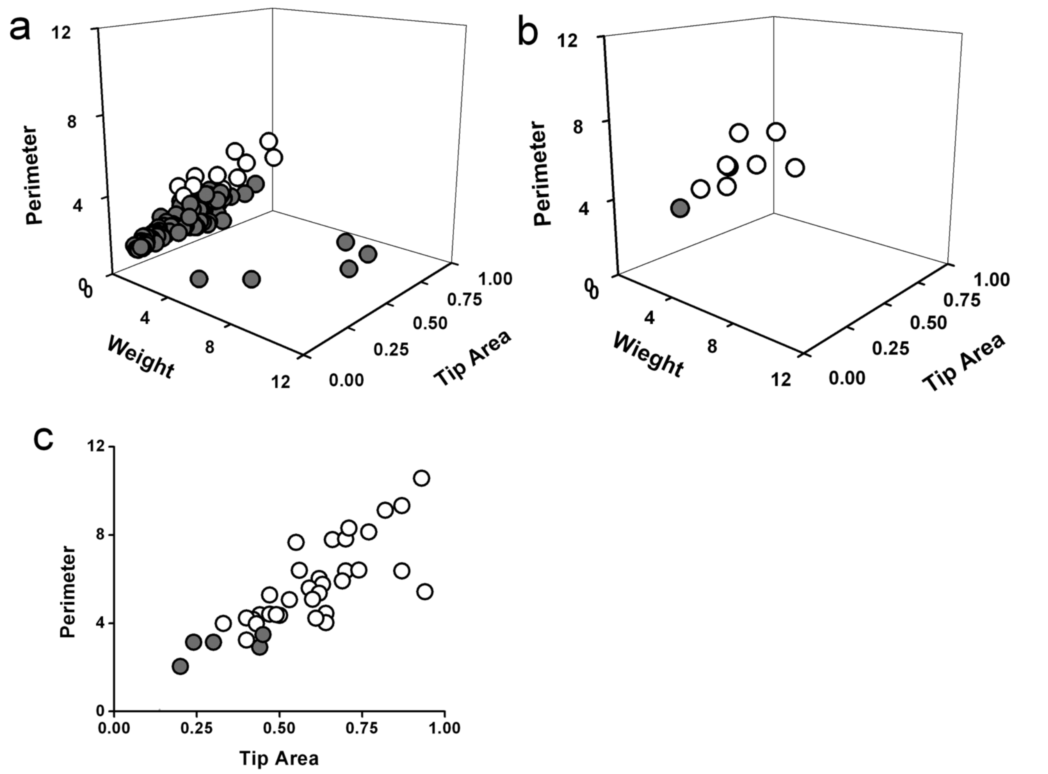

Figure 8. Size variation in Thomas' sample of arrows (a), darts (b) (Thomas 1978) and Shott's combined sample of darts (c) (Shott 1997).

8b). This dispersed pattern is usually very robust (Figure 8c), in a pattern we call the "atlatl cloud." While the cloud pattern differs among dart point types, it is a consistent quality of the dart point classes in this study.

The difference between the clustered pattern of arrows in these graphs and the more dispersed atlatl cloud pattern might seem to imply that dart points are not only larger than arrows but more variable in size. However, when the size differences between arrow and dart points are controlled, dart points can be more variable than arrow points, but not necessarily. We controlled for the size differences by calculating coefficients of variation (CV; standard deviation/mean) for the Western Great Basin and Hatwai projectile point types for all the measures used here. By expressing standard deviations as a percentage, the CV puts them on the same scale. For example, mean weight of the WGB Cottonwood Triangular points (an arrow point type) is .70 g, with a standard deviation of .32 g. The mean weight for the WGB Gatecliff Contracting Stemmed points (a dart point type) is 3.5 g, with a standard deviation of 1.5 g. However, the CVs are .45 and .43, respectively. Gatecliff Contracting Stemmed points are bigger than Cottonwood Triangular points but not more variable, at least not in weight. The CVs do not, in fact, distinguish dart points from arrow points, although darts tend to have larger CVs. However, the cloud pattern is also a product of how dart and arrow points vary along the three dimensions plotted here. The CVs may be similar, but the patterns or shapes of variation around those dimensions are not. That is what we endeavor to show with the graphs.

Results

Western Great Basin

Cottonwood Triangular and Desert Side Notched points are unambiguously classed as arrows, as

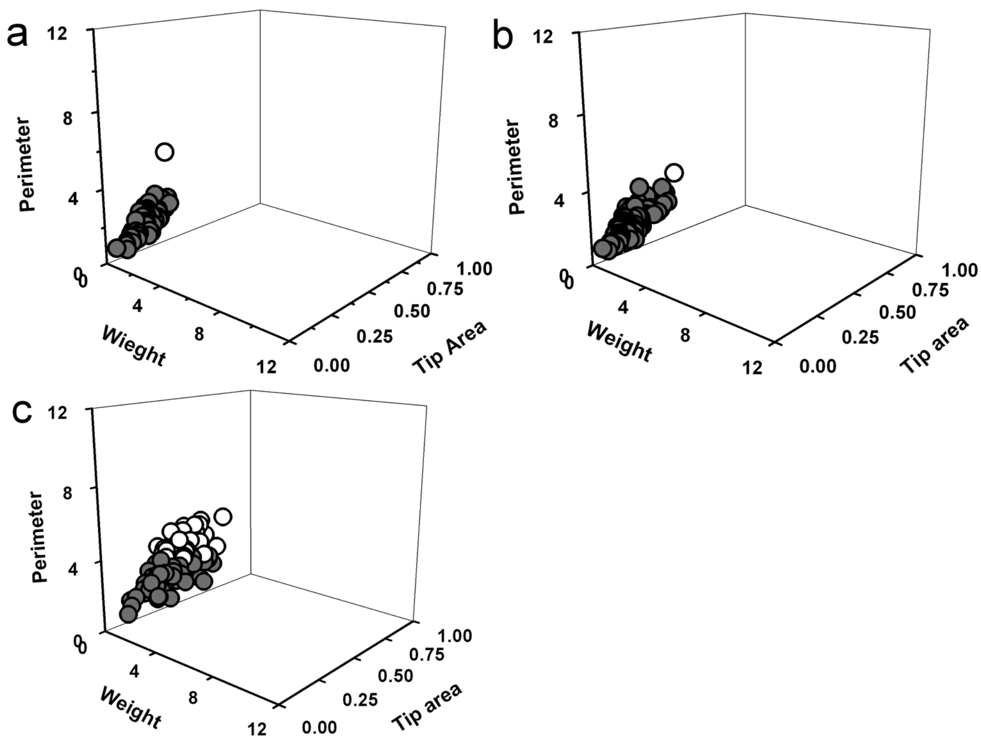

Figure 9. Size variation in Western Great Basin arrow tips: Cottonwood Triangular (a), Desert Side Notched (b), and Rosegate (c).

they should be, since they are epitomes of late Holocene arrow points. Indeed, their classification is more definitive than that of Thomas's museum arrow sample. They also exemplify the arrow pattern in the graphs (Figure 9a–b), clustering tightly in the graphs' lower right-hand space. In contrast, Rosegate points are somewhat more dispersed in the graph space (Figure 9c), although they are clearly arrow points and lack the atlatl cloud. Rosegate points are generally regarded as the first arrow points in the WGB. Interestingly, the threshold values and the means (Table 5) are virtually unanimous that Rosegate points are arrow points, while the discriminate functions are somewhat less so.

The dart results (Figure 10) mirror dart results in other studies (e.g., Nassaney and Pyle 1999), in which a substantial minority of points in a dart type are misclassed as arrows. The graphs illustrate robust atlatl clouds. Interestingly, Large Side Notched points are classed as dart points as definitively as Desert Side Notched and Cottonwood Triangular points are classed as arrow points (Figure 10d).

Hatwai

Relevant measurements and results for each Hatwai artifact are reported in Ames et al. 2007, which is available online. The classification results for the Hatwai I Windust points are mixed. By some measures they might be arrow points, and by others, dart points. Their mean weight, tip area, and neck width, however, unambiguously classify them as dart points (Table 7). The points show considerable variability (Figure 11a). This variability probably is due to several factors. Windust points were commonly extensively reworked and reduced in size during their use lives. Discarded points often have a stem and only the nub of a blade. The two smallest Hatwai Windust points fit that description (Figure 2). The variability may also reflect engineering issues with darts. According to Hughes (1998), bal-

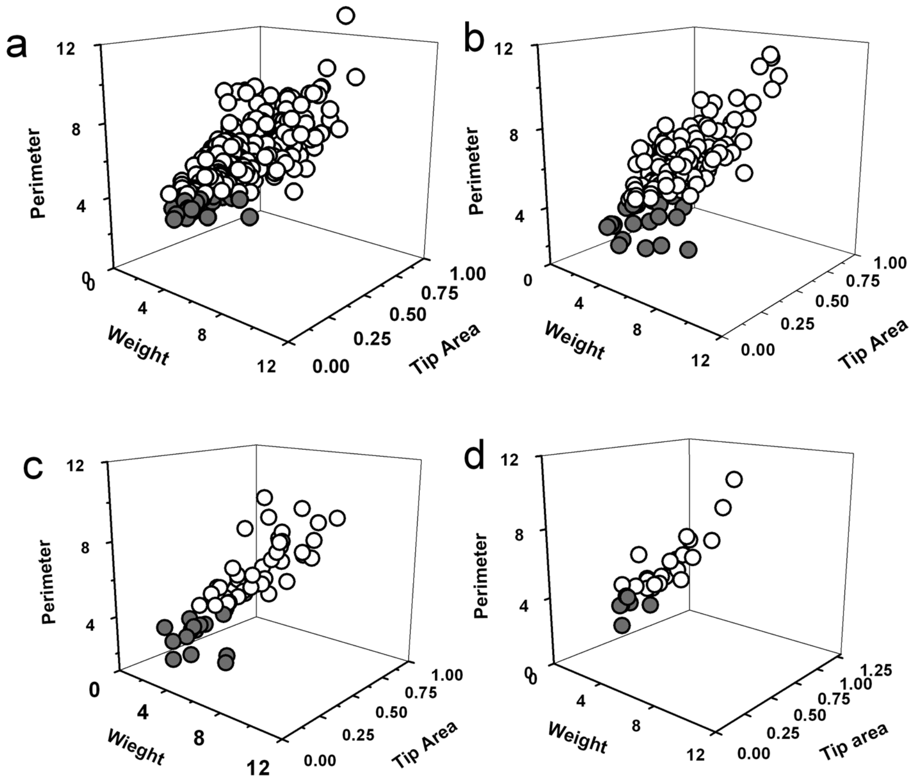

Figure 10. Size variation in Western Great Basin dart points. Elko Corner Notched (a), Elko Eared (b), Gatecliff Contracting Stem (c), Large Side Notch (d).

ance is a problem for unfletched darts, but one that can be corrected by altering the tip weight. The variability we see in Windust points meets Hughes's expectations for variability in unfletched dart points. Their sizes, however, are small enough for them to be points for fletched darts. It is generally assumed that these points armed handheld or thrown spears (e.g., Beck 1995). Our results show this assumption to be incorrect, at least for the Hatwai Windust points.

Cascade points (Figure 11b; Figure 12a, f) contrast markedly with Windust points. They not only differ in form but are much more uniform in shape and size, although Figure 12 hints at more than one size grouping within the type's narrow size limits. This apparent consistency fits Hughes's predictions for fletched dart points, and she sees a similar shift in patterns of size variability at Mummy Cave at ca. 7900 B.P., when highly variable point forms were also replaced by much less variable forms. In the Hatwai sample, however, the Cascade points as a type are classed as arrows by all measures except mean weight, and the weights of individual points are consistent with medium-sized arrow points (Table 7). Individually they are all classed as arrow points (Figure 11b), and their pattern of variability is that of arrow points rather than dart points. Unlike all of the small WGB dart points, for instance, which presumably armed fletched shafts, Cascade points have no atlatl cloud (Figure 11c).

Hatwai III points are classed as arrow points. This discussion focuses on the 119 Hatwai Eared points (Figure 4). Table 1 presents the mean measurements for all 119 and then separately for the five largest (Hatwai Eared B), which are clearly dart/spear points based on their sizes, and for the rest (Hatwai Eared A; Figure 13). All 119 are included here. Their cumulative percentage of 87 percent arrow assignment (Table 8) is higher than the cumulative percentage (85 percent) for Thomas's (1978) arrow sample. The Thomas–Shott equations classify 112 (94 percent)

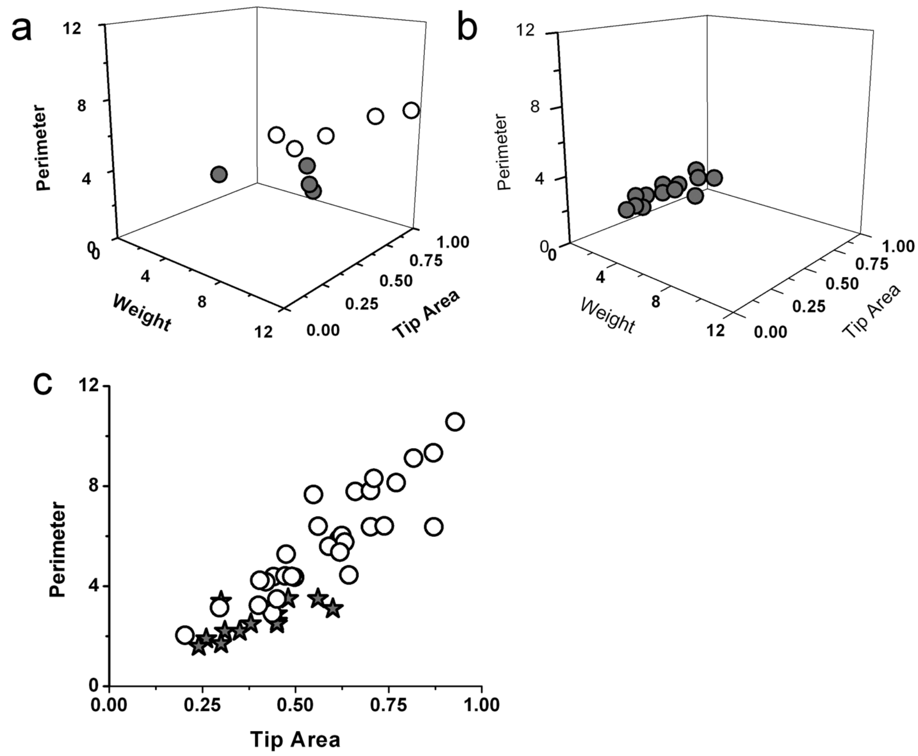

Figure 11. Size variation in Windust (a) and Cascade (b) points. Panel c compares Cascade points (gray stars) with the combined Thomas-Shott dart sample (Thomas 1978, Shott 1997) (open circles).

as arrows. Bradbury's equations estimate 92 percent to be arrows. Hughes's thresholds for weight (87 percent), tip area (98 percent), and perimeter (92 percent) unambiguously class them as arrows (Figure 13, Table 8). Neck widths are the only exception to this unanimity, classing only 67 percent as arrows. Patterns of size variation are comparable with both Thomas's sample of arrow points and WGB Rosegate points (Figure 14). We conclude from all of this that Hatwai Eared points are unequivocally arrow points. Other Hatwai point types unambiguously classified as arrow points include Rabbit Island Stemmed, Columbia Stemmed, and Hatwai Small Side Notched (Tables 6–7, Figure 15). Four Desert Side Notched points from the Hatwai IV component are also included here.

There are no Hatwai projectile point types that are classified as dart points as unambiguously as are the WGB Large Side Notched, Elko, or Gatecliff series. However, the sample does include some individual projectile points that may have functioned as dart points and possibly as spear points (Figure 15a). In addition, some point types classed as arrows may have served as both arrow and dart points or include both. The Nespelem Bar and Quelomene Bar point types (Figure 15c–d, Tables 6–7) are excellent examples. Nespelem Bar points are relatively large, heavy points with broad neck widths and large tip areas. They appear to fall into two size groups, the larger of which has an attenuated atlatl cloud. Quelomene Bar points are generally smaller but also separate into large and small groups. These larger groups may contain dart points.

To summarize, Hatwai I Windust points, dating from 10,800 B.P. to 9800 B.P., are dart points. Hatwai II Cascade points, dating from 8200 B.P. to before 4400 B.P., may include both arrow and dart points but are arrow sized, while most Hatwai III points, dating between 4400 and 2800 B.P., are clearly arrow points.

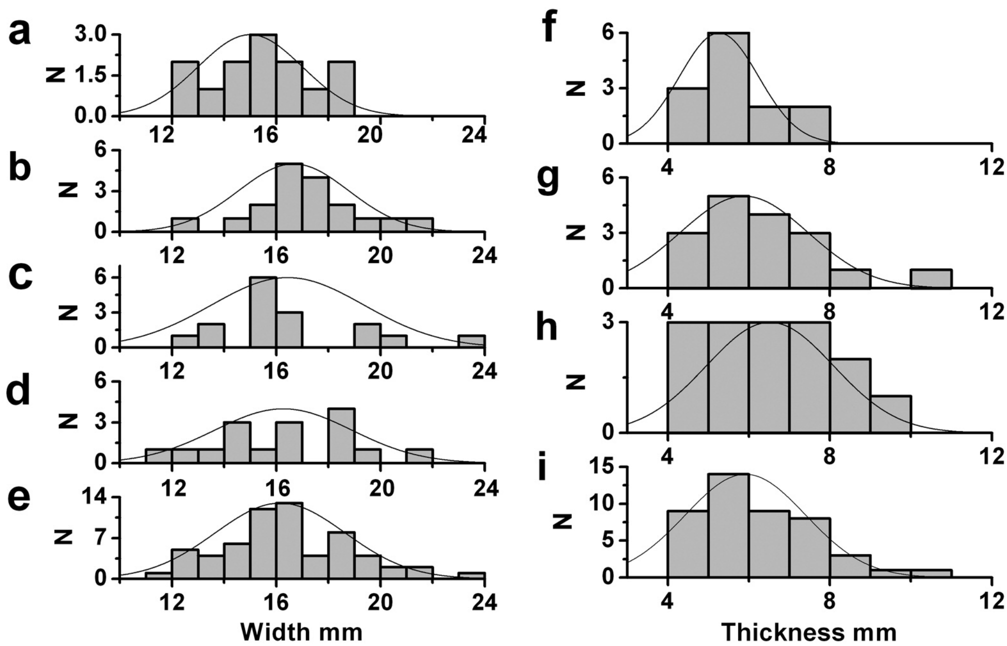

Figure 12. Cascade point widths of the Hatwai (a), Granite Point (b), Pipeline (c), Ryegrass Coulee (d) and Combined (e) samples and thicknesses of the Hatwai (f), Granite Point (g), Ryegrass Coulee (h) and Combined (i) samples.

Lower Snake River Region

Our LSR data are presented in two graphs and a table. In the first graph, the mean weights (Figure 16a), perimeters (Figure 16b), and tip areas (Figure 16c) for each type are plotted by phase. In the second graph (Figure 17), the means are binned and plotted by phase. In both sets of graphs, dashed lines indicate Hughes's threshold values. Because we seldom had measurements for individual artifacts, numbers of arrows and darts were estimated by counting all the members of a class as either arrows or darts if the class itself was classified as arrow or dart.

Because the LSR data are based on mean values, sample size and number of projectile point types per phase and number of artifacts per type are important (Table 9). The late Cascade and Nimipu phases have the smallest sample sizes, and Windust, the largest. The graphs mix taxonomic levels. For example, Rice (1972) recognized one basic regional Windust type with multiple subtypes. The subtypes are used in the graphs rather than one Windust type. Cascade points are a single, regional type represented at four sites in these data; hence they appear four times on the graphs. We did that to avoid calculating a mean of the means of the four sites. The mean number of points/class figure for the early Cascade phase is deceptive, because 79 of the 85 points are in a single class from the Granite Point site (Figure 1). The data for the late Cascade subphase combine regional types with site-specific groups. After the late Cascade subphase, all the types are site specific or even specific to a single site component. However, in the absence of measurements of individual artifacts, they do a reasonably good job tracking artifact sizes because the number of types is high while the number of artifacts/type is low.

We applied the Thomas–Shott equations and calculated perimeter and tip area for projectile type minimum, mean, and maximum for the 125 LSR projectile point types. In the interests of space only means are reported here. The complete data are reported elsewhere (Ames et al. 2007) and are available online. The classification of specimens as arrow or dart in Table 9 is based on evaluation of all results.

The threshold values for Windust points reinforce the conclusion that they are dart points, as does the broad spread of threshold values among Windust point subtypes (Figure 16). This spread

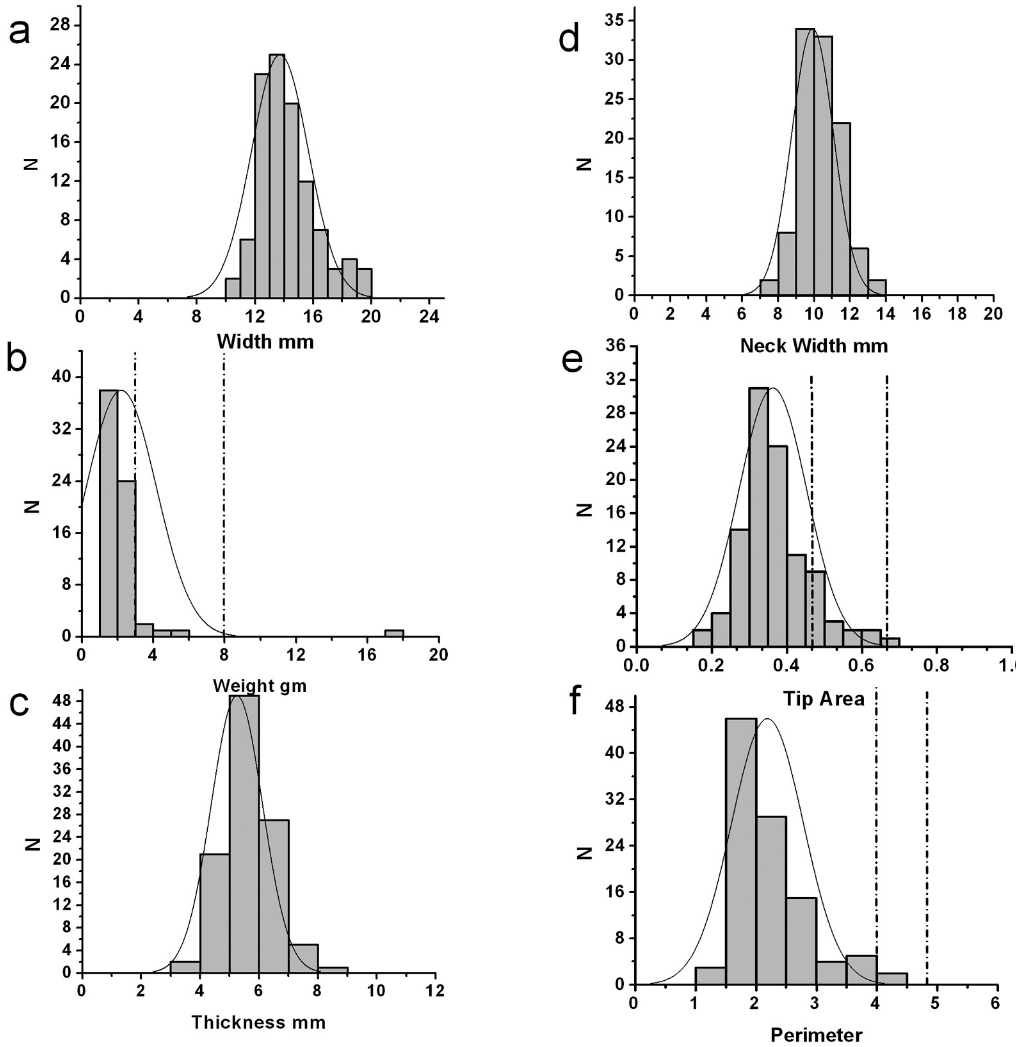

Figure 13. Hatwai Eared sub-type widths (a), weights (b), thicknesses (c), neck widths (d), tip areas (e) and perimeters (f). Dashed lines indicate Hughes' (1998) thresholds (Table 4).

mirrors that of the Hatwai Windust sample (Table 9). The type means for Cascade points indicate that Cascade points are overwhelmingly arrow points. As it happens, it is possible in this one LSR case to check that inference. Nisbit (1981:111) took width, length, and thickness measurements on 17 of the 79 Cascade points recovered at the Granite Point site (Figure 1), the only such set of LSR measurements we have. The Granite Point Cascade points are somewhat larger than the Hatwai points (Figure 12b, g), but most are arrow sized. Width is unimodally distributed among the Granite Point artifacts. The Thomas–Shott single-variable equation classes three (14 percent) as dart points; Hughes's perimeter threshold classes the same three as dart points; and her tip area classes nine (42 percent) as large arrow/small dart points. These numbers and the graphs again suggest that Cascade points as a type are arrow points or include both arrow and dart points.

The graphs and table show important temporal trends. Although the late Cascade sample is small, both arrow and dart points are indicated. The sample is too small to draw any other conclusions. The Tucannon phase is very similar to the contemporary Hatwai III component in that dart points were

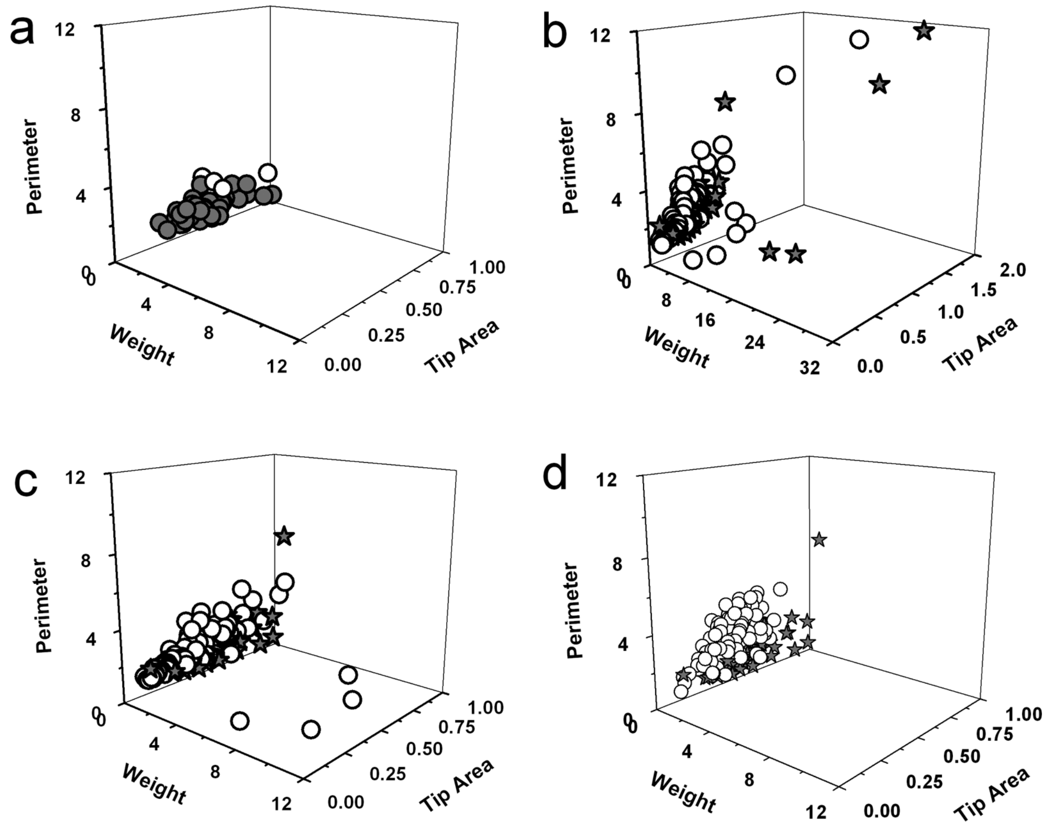

Figure 14. Metric variability in Hatwai Eared Points (a) Hatwai Eared points compared to the full size range variation in Thomas' Arrow sample (Thomas 1978) (b), Hatwai Eared points compared to the Thomas arrow sample using the standard x, y and z axis sizes in this paper (c) and Hatwai Eared compared to Rosegate points.(d). In panel a, open circles are points classed as darts, gray circles are arrows. In the other panels, gray stars are Hatwai Eared points, open circles the other points.

present, but the majority of the assemblage seems to be arrow points. The overall proportion of arrow points to dart points in Hatwai III (that is, 85 percent arrows) is the same as the proportion of arrows in the LSR region's Tucannon phase (Table 9).

In the early Harder phase, the relative number of dart points increased, from 15 percent of the total number of projectile points in the preceding Tucannon phase to almost 42 percent (Table 9), the highest percentage of dart points in the LSR assemblages after the Windust phase. Arrow and dart points also diverged in size. This divergence probably began during the Tucannon phase but is quite evident in the early Harder phase. Mean weights shift toward both the small and large tails of the distribution, and the slightly bimodal distribution of tip areas during the Tucannon phase becomes strongly bimodal in the early Harder phase. Close examination of mean perimeters (Figure 17b) shows that both tails of the distribution fatten in the early Harder phase. These patterns are commensurate with a gradual divergence of dart and arrow points. The patterns shift markedly in the late Harder phase with the visible appearance of small arrow points and the strongest distinction between arrow and dart points of the entire sequence. This shift may indicate that local arrow point styles were replaced with a new, smaller arrow point. At the same time, darts both declined in numbers and became metrically very distinct. Later in time, in the contact-period Nimipu phase (which dates to after the introduction of the horse), the size of arrow points is even smaller, even though people continued to use darts.

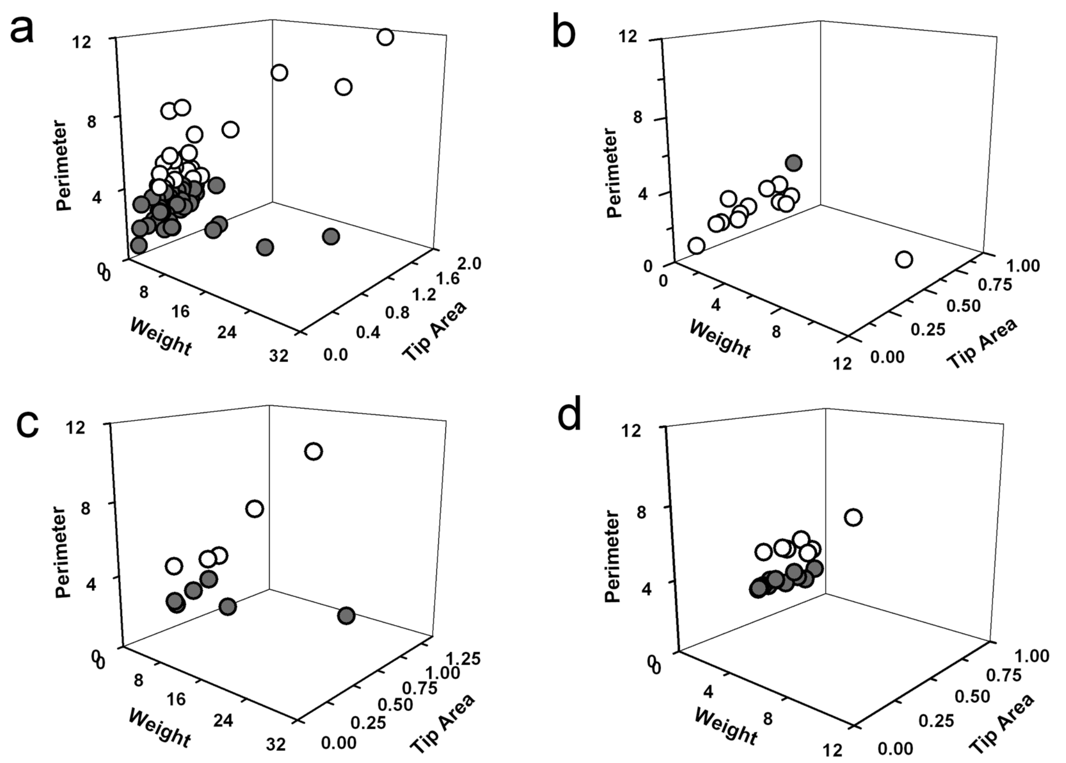

Figure 15. Metric variation in other Hatwai III point styles, including all styles (a), Rabbit Island Stemmed points (b), Nespelem Bar Points (c) and Quelomene Bar Points (d).

In sum, the LSR data indicate that bows and arrows were present during the early Cascade subphase (8500–7000 B.P.). Use of atlatl darts was relatively common during the late Cascade (7000–4500 B.P.) but declined during the Tucannon phase. Dart use revived during early Harder (2500–1500 B.P.). The atlatl was replaced by the bow and arrow during the late Harder phase (1500 B.P.–contact), although a very small number of darts were still in use in the Nimipu phase (postcontact). The size and morphology of arrow points and dart points diverged metrically during this lengthy period, with maximum divergence during the late Harder phase.

PGT-PG&E Pipeline Project

The Pipeline analytical team took a range of width and length measurements, including maximum blade width, base width, and neck width, but not thickness or weight measurements. Therefore we could use only the Thomas–Shott single-attribute (shoulder width) equation. Here we assume that maximum width and shoulder width are generally the same. The results are quite similar, and in some cases identical, to those already described (Table 10). The six Windust points separate metrically into three arrows and three dart points, almost exactly the same breakdown as the sample of 11 Windust points from Hatwai. The assignment of the Cascade points is quite similar to the Granite Point proportions; they are similar in size to both the Hatwai and Granite Point Cascade points (Figure 12c), with a trimodal width distribution similar to the pattern seen at Hatwai.

The shifting proportions of darts and arrows through time in this area are similar to those observed in the LSR region (Table 10). Arrows were introduced in the early Holocene; the proportion of darts declines in the middle Holocene and then rises sharply among point types that were introduced after 3000 B.P. All of the unambiguous dart points in the sequence postdate 3000 B.P., and darts are virtually absent among the point types that were introduced after 2000 B.P.

Looking at point types only, three arrow point types and three dart point types were introduced in the early Holocene (Table 10). Only arrow point types were introduced in the middle Holocene (although early Holocene forms persisted). After 3000 B.P., three types of dart points and one new arrow point type were introduced. The newly introduced dart point styles again are the most distinctive types of dart points in the entire sequence. After 2200 B.P., new point styles include five arrow point types but no darts.

Discussion

Several conclusions can be drawn from the multiple lines of evidence and multiple data sets presented above. First, the atlatl was present on the Columbia Plateau by 10,800 B.P., either fletched or unfletched. Patterns of metric variation suggest unfletched darts; point sizes suggest both were present. Second, Cascade points are plausibly arrow points. Third, the bow and arrow were present on the Columbia Plateau in large numbers no later than 4400 B.P. Fourth, both projectile systems were used together over several millennia. Fifth, after 3000 B.P. darts and arrows became increasingly differentiated; and sixth, the atlatl was in use on the Plateau in small numbers after 1000 B.P. Before briefly discussing some of the ramifications of these conclusions we explore two alternative explanations.

It has been suggested to us that the early and middle Holocene presence of arrow-sized points at Hatwai is a consequence of our "monitoring position" (Thomas 1982) vis-à-vis projectile point use lives. The suggestion was made for Hatwai III that the assemblage is composed of dart points reworked down to arrow size at the end of their use lives. This argument is different from the rejuvenation model of Flenniken and Raymond (1986) and others. That model posits that Great Basin dart point types actually represent different stages in the use lives of individual points as they were reworked and rejuvenated after breakage. This argument, rather, is that reworking and rejuvenating dart points eventually make them arrow sized and that this work occurs in residential sites. Consequently, dart-sized Hatwai Eared points are elsewhere on the landscape. Many Hatwai Eared points are clearly reworked (Figure 4), but the sample of 119 is sufficiently large that if Hatwai Eared points were dart points, the full size range should be represented (Zeanah and Elston 2001), that is, there should be an atlatl cloud, even if an attenuated one. This expectation is strengthened by the levels of repair and discard at Hatwai. Of the 119 Hatwai Eared points, only a third (43) are complete; most of the rest lack tips or were snapped above the shoulders. If Hatwai Eared points are actually dart points, we should find dart-sized points among the complete points, which presumably would be ready at hand to replace the discarded points. Just two complete points are dart sized, and one is small dart/arrow sized; the rest are arrow sized. What we appear to be seeing are arrow points being reworked into smaller arrow points, probably while they were still hafted (Zeanah and Elston 2001). The argument is further undercut by the remarkably parallel results in three large but differing data sets of points from a variety of contexts. Arrow-sized points, for example, are common in all three Plateau middle Holocene samples.

It has also been suggested to us that Plateau projectile points are small relative to those found elsewhere (e.g., Ames 2000) and therefore the various measures we employ here will not work on the Plateau: in essence dart points on the Plateau were arrow point size. We tested the first part of this assertion by plotting the weights, neck widths, perimeters, and tip areas of the WGB, Hatwai, and LSR points (Figure 18). We again were unable to include the Pipeline points because the relevant measures were not reported. The Plateau points are indeed generally smaller than the WGB points. However, because the LSR data are means, potential size variability there may be compressed. To test that possibility, we calculated sample means from the means of the WGB and Hatwai point types. Those means are smaller (Table 11) but do not completely eliminate the size differentials between the WGB points and the LSR and Hatwai points. We believe that the difference at least partially results from the Columbia Plateau samples containing more arrow points than does the WGB sample. Arrow points make up 53 percent of the WGB sample we used. Among the Plateau samples, and assuming our assignments are correct, arrows are 69 percent of the Pipeline points and 85 percent of the Hatwai points. Of the LSR point

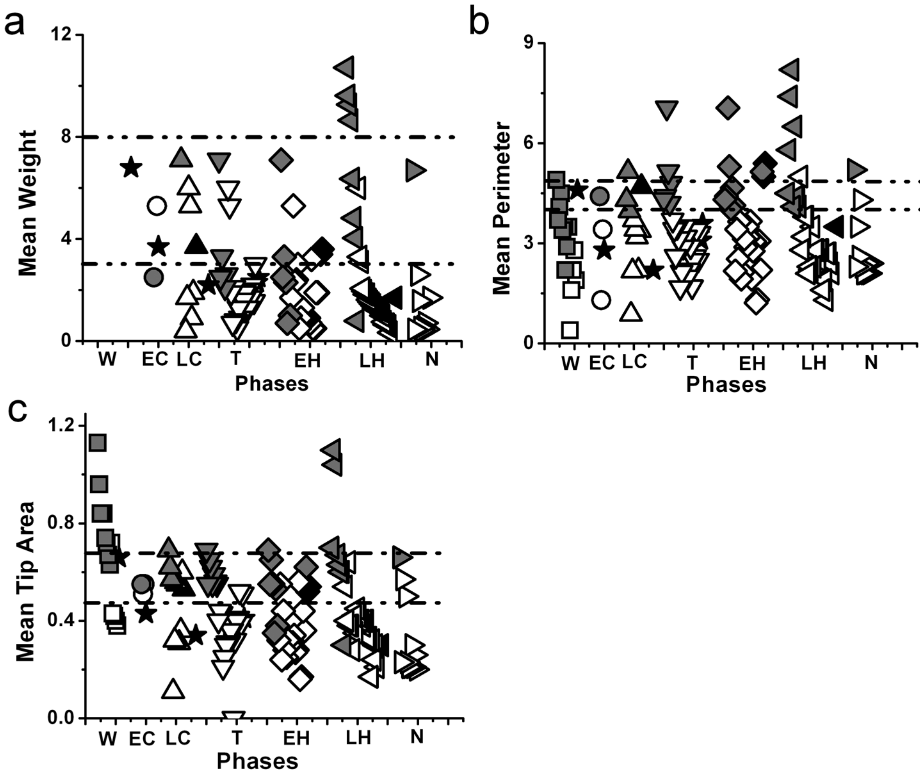

Figure 16. Mean weights (a), perimeters (b), and tip areas (c), class by phase of Lower Snake River projectile point types. Stars are Hatwai point classes, including Windust, Cascade and Hatwai Eared. Dashed lines indicate Hughes' (1998) thresholds (Table 4).

types, 69 percent are classed as arrows, and we estimate that 63 percent of the artifacts are arrow points (Table 9). If our assignments are wrong, one is left with the interesting problem of how and why people on the Plateau successfully armed their darts with arrow-sized points until the late Holocene when they started using larger dart points. The second part of the assertion—that Plateau dart points will be so small that they will all be classed as arrows—is belied by all the measures employed here working very consistently across all four data sets; the graphing is particularly persuasive in this regard. Thus, we find this argument unconvincing.

The evidence presented here argues that Windust points armed either unfletched or fletched darts. Archaeologists have generally assumed that the large stemmed points of the late Pleistocene/early Holocene West armed thrown or handheld spears (e.g., Beck 1995). This appears to be incorrect. If these Windust points were used on unfletched darts, this interpretation would help account for their formal and metric variability. As noted above, balance is a problem for unfletched darts, and manipulating point sizes is one way of balancing the darts (Hughes 1998). We speculate that some of this manipulation might have occurred when points were originally made, but some might have been done on the fly during hunts, with hafted points being worked down as they broke. Hughes notes that the tips of unfletched darts may be "designed to store extra weight, i.e. long and thick" (1998:368). Given the energy expenses of reworking and rehafting dart points (Zeanah and Elston 2001), it is plausible that Windust points were designed to "store extra weight" and to be worked down during their use lives while still providing balance for the shafts they armed.

The next issue is whether Cascade points are arrow or dart points. The separate lines of evidence presented thus far indicate that most are arrow

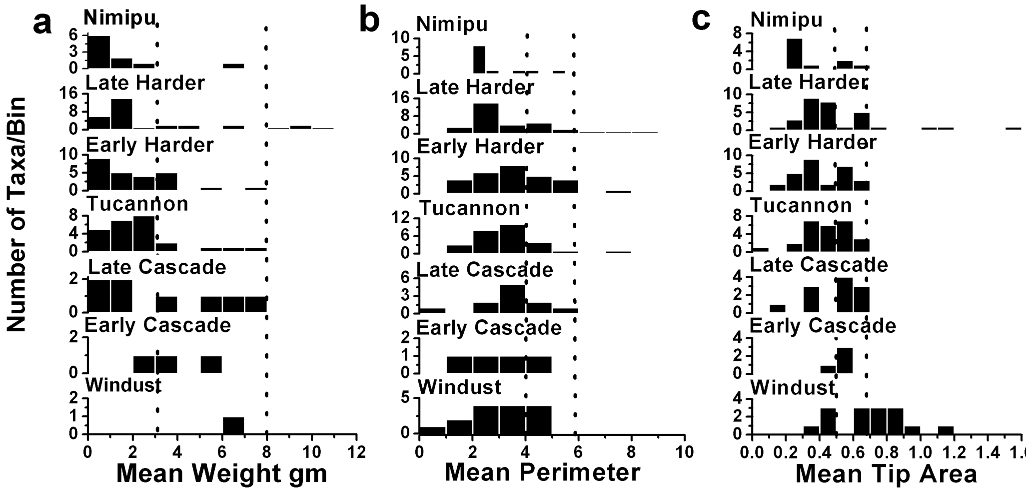

Figure 17. Mean weights (a), perimeters (b) and tip areas (c) for Lower Snake River Projectile points. Dashed lines indicate Hughes' (1998) thresholds (Table 4).

points. This suggestion is likely to be very controversial and certainly will not be resolved to everyone's satisfaction without physical reanalysis of one or more of the type collections, such as the one from Granite Point. Part of the problem, as noted above, is that different projects reported different measurements in different ways, so we do not have a single large, consistent data set. In any case, the introduction of Cascade points marked a significant formal shift from Windust points, a shift that, if nothing else, our data indicate is insufficiently appreciated and problematized. It is likely that the shift was, at least in part, a change in hafting technology. Musil (1988) reviews two forms of hafting, split stem (three variants) and socketed, for early Holocene points in western North America. He does not include Cascade points but does discuss contracting-sided points (e.g., Haskett), which would include Cascade points. He argues that stemmed points, such as Windust points, were hafted in split hafts while contracting-sided points were in socketed hafts. Fedje et al. (2008) suggest another method of hafting foliate points in which shafts have beveled ends and points are attached to the shaft against the bevel. We know of no evidence indicating that arrows cannot have socketed or beveled hafting or that would explain the formal uniformity of Cascade points in terms of hafting.

A related issue is Amick's (1994) concern as to whether the Thomas–Shott equations are applicable to unstemmed lanceolate points simply because there were none in Thomas's original ethnographic sample. He raised the issue because the equations classified a high percentage of a large sample of Folsom points as arrows. Our use of multiple measures addresses this issue. Additionally, Hughes's observation that the shaft cannot have a diameter greater than its arming point's width is valid regardless of the point's shape. In this study, we assumed that Cascade points' maximum width is the equivalent of shoulder width for the purposes of using Shott's single-variable equations.

We compared the size variation among Hatwai's Cascade points with the only lanceolate points available in the WGB data set: the Humboldt series points (Figure 19). Humboldt points have ambiguous classification results (Tables 4–5), which mirrors uncertainty about their function, whether they are dart points or knives, for example (Yohe 1998). Cascade points are generally smaller, and their variability is more circumscribed. We can make additional statements about the sizes and uniformity of Cascade points using the three samples discussed here, plus one additional sample. Munsell (1968:29–36) reports measurements on 16 Cascade points recovered at the Ryegrass Coulee site (45KT88) in the western Columbia Plateau (Figure 1). They date to the middle Holocene. The assemblage is unusual because it contains microblade cores and microblades but is otherwise a typical Cascade assemblage. Munsell's descriptions and the illustrations make it clear that these are in

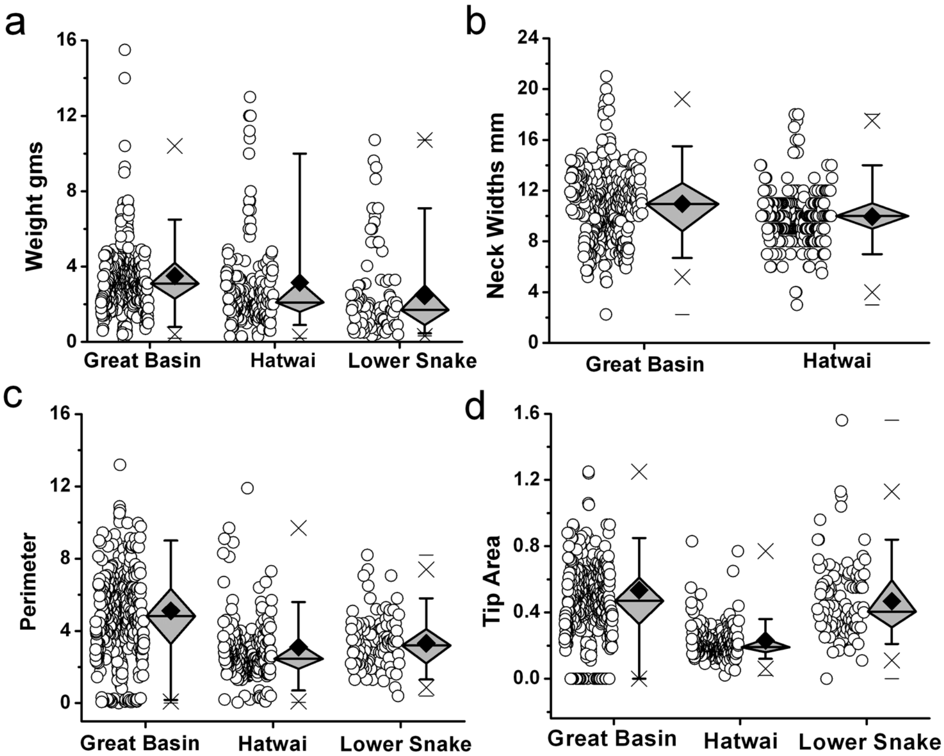

Figure 18. Box plots comparing sizes of Western Great Basin, Hatwai and Lower Snake River projectile points on four dimensions: weight (a) neck widths (b), perimeter (c) and tip area (d). The Lower Snake River figures are class means; the Western Great Basin and Hatwai figures are individual points.

fact Cascade points (Figure 12d, h). Combining the four collections produces a sample of 62 points, with maximum width measurements available for the entire sample (Figure 12e) and thickness measurements on 46 of the 62 points (Figure 12i, Figure 20a–b). We have weights only for the Hatwai points.

The majority of the Cascade points in the combined sample (Hatwai, Granite Point, Pipeline, Ryegrass Coulee) are classed as arrows. The Thomas–Shott single-variable equations class 53 (85 percent) as arrows and nine (15 percent) as darts. Of the 46 for which we can calculate tip area and perimeter (Figure 20a–b), 25 (54 percent) have tip areas below Hughes's arrow/dart threshold of .47. Sixteen (35 percent) of the points measure between .47 and .62 (large arrow/small dart); and five (11 percent) are above .74 (dart). Tip area measurements below .62 are strongly trimodal (Figure 20a), again suggesting that the smaller Cascade points include three size variants. Perimeters are tightly circumscribed; 41 points have perimeter values between 1.6 and 4.0 (arrow), and five are between 4.0 and 5.4 (large arrow/small dart). Actually, variation is even more constrained: 36 (78 percent) have perimeters below 3.5. This uniformity suggests consistent adherence to very narrow limits on shaft diameter despite the size variants noted above. The pattern of metric variation in the combined sample (Figure 20c) is very similar to the Hatwai Cascade sample; it lacks the atlatl cloud (Figure 11b–c). This result cannot be attributed to sample size. The scatter of points representing this cloud is clearly visible in equivalently sized samples of darts (e.g., the combined Thomas–Shott dart sample [Figure 8c], WGB Gatecliff Contracting and Split Stemmed [Figure 10c], and WGB Large Side Notched [Figure 10d]) as well as the larger WGB dart samples. In sum, most Cascade points are consistently arrow sized along a number of dimensions, and they generally vary metrically like arrows, rather than like darts. We therefore argue that many Cascade points were arrow points. Some, perhaps the largest size variant, could have been dart points.

The final issue is the chronology of Cascade points. The dating of the sample from Hatwai is not very precise, between 8200 and 4400 B.P. That can be narrowed using points from the Pipeline project and Granite Point. Six of the 15 Pipeline Cascade points were recovered at two sites (35DS557 [Atwell and Hodges 1995], 35JE51B [Pettigrew and Hodges 1995]; Figure 1). At both sites, the points were below Mazama ash, which, as noted above, dates between 6700 and 7000 B.P. At site 35JE51B, the associated sediments produced two radiocarbon dates: 6770 ± 60 and 7035 ± 65 (Table 2; Pettigrew et al. 1995). Five of these six points are classed here as arrow points, and one is classed as a dart point. At Granite Point, Cascade points were recovered both above and below the Mazama ash (Leonhardy 1970). The post-Mazama late Cascade component at this site has a terminal date of ca. 5000 B.P. (Leonhardy 1970). Although Nisbit (1981) does not indicate from which Granite Point Cascade assemblage he drew his sample (early or late Cascade), only three complete Cascade points are associated with Granite Point's late Cascade component (Leonhardy 1970). Thus, at a minimum, we know that 14 of the 17 individual points that Nisbit measured are from the pre-Mazama early Cascade component. In short, arrow-sized Cascade points predate the Mazama ashfall.

Turning to Hatwai III, 85 percent of all the points are also classed as arrow points, virtually the same percentage as in the earlier Cascade phase, as also seen during the contemporary Tucannon phase on the LSR and during the later late Harder and Nimipu phases, when the arrow is generally thought to have replaced darts (Table 9). Hatwai Eared points, which date between 4400 and 2800 B.P., are clearly arrow points. While they presently seem limited regionally to the southeastern Plateau, other arrow point styles, such as Rabbit Island Stemmed points, are common mid-Holocene Plateau types that occur across the whole region (Lohse and Shou 2008; Pettigrew et al. 1995).

We find the ubiquity of arrows in large numbers on the Plateau by 4400 B.P. to be a surprise. However, this pattern is remarkably consistent across the three Plateau data sets and appears to be different from patterns reported elsewhere (e.g., Nassaney and Pyle 1999). In other regions, arrows may be present but apparently are not numerous. Hatwai III points are technologically distinct from Cascade points (Ames 1984) and seem, with other notched point types in the region, to be part of the widespread side- and corner-notching technique that may have developed in the eastern Great Basin ca. 8000 B.P. (Beck 1995), arriving on the Plateau after 7000 B.P. A plausible hypothesis is that corner-notched arrows represent an adaptation of that hafting technique to arrows.

Our data also show that the two weapon systems have a long and complex mutual history on the Plateau, perhaps similar in some ways to that documented by Shott (1993) for the late Woodland in the Midwestern United States. On the Plateau, the bow and arrow do not initially replace the dart. Atlatls and bow and arrow technology are used together for millennia, countering the general expectation that the dart would disappear after the bow and arrow became common. According to this view, the bow and arrow's apparent clear superi-

Table 11. Size Measurements for the Western Great Basin, Hatwai and Lower Snake River Samples.

Attribute	Mean	Std Dev	Std. Error	Median
WGB Weight (gm)	3.50	3.32	0.17	3.10
Hatwai Weight (gm)	3.15	3.73	0.25	2.10
LSR Weight (gm)	2.45	2.31	0.24	1.70
WGB Neck Width (mm)	10.96	3.73	0.19	10.95
Hatwai Neck Width (mm)	9.95	2.15	0.14	10.00
WGB Perimeter	5.12	4.39	0.22	4.82
Hatwai Perimeter	3.10	6.30	0.38	2.45
LSR Perimeter	3.31	1.37	0.13	3.19
GB Tip Area	0.53	0.88	0.04	0.47
Hatwai Tip Area	0.23	0.29	0.02	0.19
LSR Tip Area	0.47	0.23	0.02	0.41

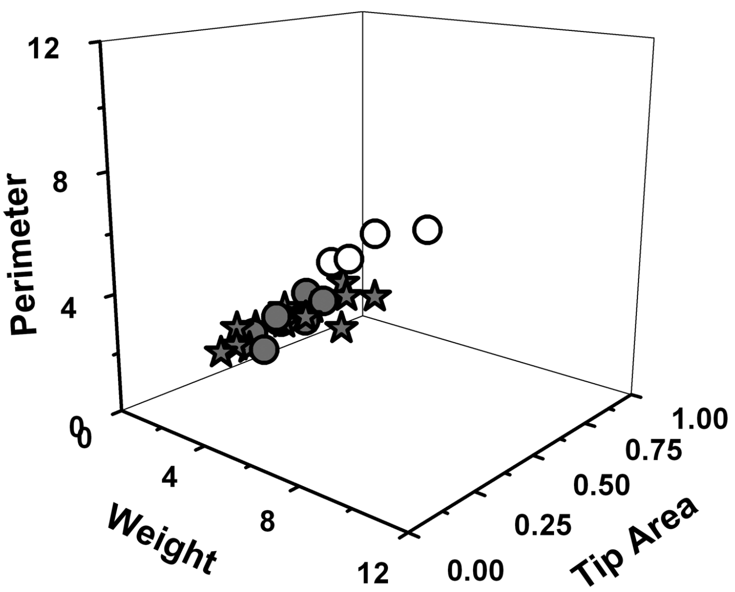

Figure 19. Size variation among Hatwai Cascade (stars) and Humboldt Series points (circles). Humboldt points are the only lanceolate points in the WGB sample. Open symbols represent points classed as darts, gray symbols points classed as arrows by the Thomas-Shott equations (Shott 1997).

ority over the atlatl would result in rapid replacement of the older technology, once the bow and arrow were readily available (e.g., Hughes 1998; Raymond 1986; Seeman 1992 and citations therein). This model has been debated (see Shott 1993 for counterarguments; also Cattelain 1997; Yu 2006), and we are not the first to document the persistence of darts after the appearance of the bow and arrow (e.g., Erwin et al. 2005; Shott 1993; VanPool 2006, Yohe 1998), although we may be the first to propose such a lengthy period of co-use in North America. The late Holocene revival of darts, in both numbers and form, however, is particularly interesting and important. Dart points first became both more numerous and more differentiated from arrow points and then became less common. Viewed from an evolutionary standpoint this pattern, analogous to diversifying selection and niche specialization, records increasing functional specialization, with arrows and darts becoming even more differentiated and task specific as darts tended toward extinction.

Lyman et al. (2008) present a useful general model based on evolutionary concepts of the transition from atlatl dart to bow and arrow against which to compare our results. Our data were not developed as an explicit test of their model, and they use only one Plateau site in their test. They argue that, following the introduction of the bow and arrow in a region, dart and arrow points will display increased formal variation as artisans experiment with differing forms to arm their weapons, selecting the more effective and abandoning the less effective. With time, formal variation should decline as the less effective forms are winnowed out. Their review of data supported these predictions. However, if the bow and arrow were present during the early Cascade phase, our results do not support their expectations. Early Holocene point assemblages on the Columbia Plateau are often exclusively Cascade points, although stemmed points are also present. Late Cascade point assemblages generally have two styles, Cascade and large notched points. It is not until after 5000 B.P. that projectile point formal variation increases significantly. On the other hand, if we are wrong about Cascade points and the bow and arrow were introduced ca. 5000 B.P., the pattern conforms better to Lyman et al.'s model, though still not fully. Common mid-Holocene point styles on the Plateau include foliate, stemmed, basal, and corner-notched forms, the diversity of forms they predict. Rather

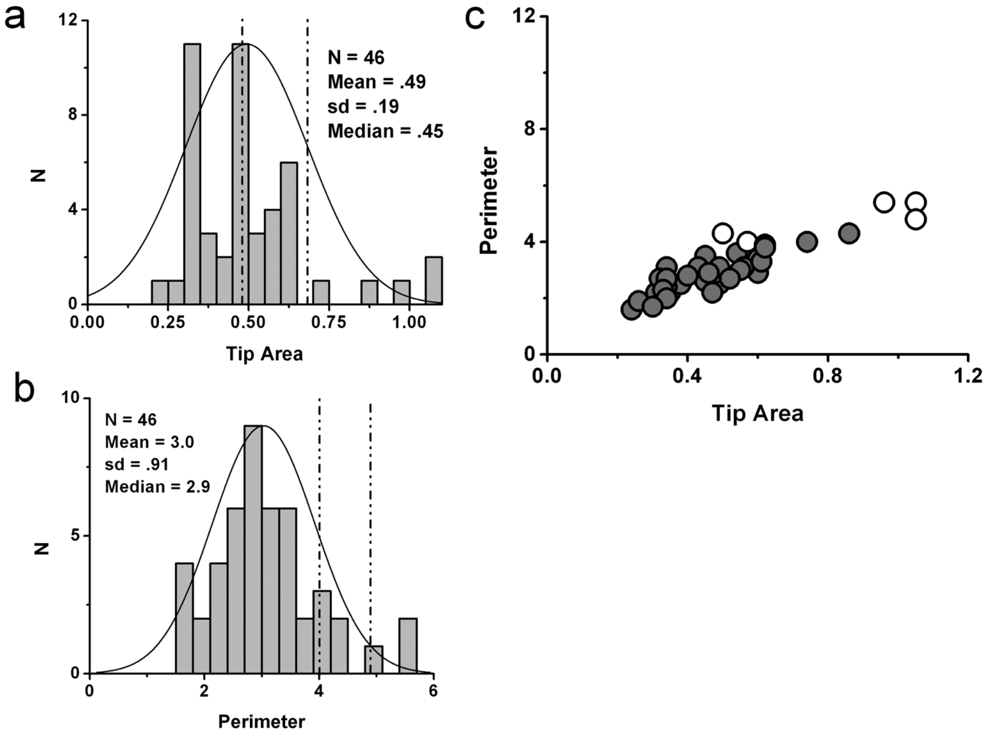

Figure 20. Tip areas (a, c) and perimeters (b, c) for Cascade points from Hatwai, Granite Point, and Ryegrass Coulee. Dashed lines indicate Hughes' (1998) thresholds (Table 4).

than gradually disappearing, however, dart points persist in low numbers for 2,000 years and increase in frequency for a time after 3000 B.P. while at the same time diverging strongly both formally and metrically from arrow points.

The divergence of dart and arrow points in the Plateau may have begun as early as the Tucannon phase, which would mean that it proceeded very slowly and perhaps imperceptibly to the participants. Shott (1993) also documents an apparently gradual shift to the bow and arrow in the Midwestern United States. This observation has interesting implications for models of cultural transmission and evolutionary cultural theory in general, especially in terms of evolutionary mode and tempo that are beyond the scope of this particular article. The typological practices of LSR archaeologists may obscure the predicted pattern, but that argument cannot be made for the Hatwai or Pipeline collections. In any case, our data indicate that on the Columbia Plateau at least, neither weapon system was sufficiently better than the other under all circumstances over the long term to the extent that one would completely replace the other. People used both bow and arrow technology and the atlatl for millennia. It is clear, however, that the role of the atlatl did become much attenuated after 1000 B.P.

This pattern casts a different light on the widespread appearance of classic small arrow points around 1500–1300 B.P., which seemingly replaced both darts and larger arrow points across the entire continent (e.g., Bettinger and Eerkins 1999; Blitz 1988; Erwin et al. 2005; Nassaney and Pyle 1999). This replacement is usually explained as the result of the initial appearance and diffusion of bow and arrow technology. However, on the Plateau, at least, it may have been the result of some significant improvement in that technology. We suggest above that the small "classic" points replaced a local tradition of arrow point. Beck (1995) observes that the appearance of these small points (e.g., Desert

Side Notched) marks a revival of side notching that had already disappeared among dart points in the Great Basin several millennia earlier. In addition to side notching, some varieties of these small late points have very narrow stems, sometimes referred to as "pin stems." In both cases, the hafting elements on the points seem fragile (Beck 1995). We do not mean to suggest that improvements in hafting alone account for the rapid spread of these small points but, rather, any changes in hafting may have been part of a complex set of design/performance improvements for the bow and arrow that finally rendered the atlatl obsolete, except perhaps under very specialized conditions. These data also indicate that the appearance of the bow and arrow by itself does not explain the well-documented and widespread increase in warfare in western North America (Chatters 2004; Lambert 2002; Maschner 1991) in the late Holocene.

The final empirical implications we wish to explore have to do with the origin of the bow and arrow in the western hemisphere. If Cascade points are actually arrow points, then the bow and arrow were present in western North America no later than 7000 B.P. and, given the chronology of Cascade points, by 8500 B.P., if not earlier. Cascade points are a local manifestation of a widespread bifacial technology in northwestern North America with apparent roots in western Beringia that archaeologists have recognized for a long time (e.g., Butler 1961; Smith 1954; chapters in Carlson and Magne 2008). Bifacial foliates of varying sizes are among the diagnostic artifacts of this manifestation and have considerable time depth. They are contemporary with Windust, for example, on the northern British Columbia and southeast Alaska coasts (e.g., Dixon 2008; Fedje et al. 2008) and have strong similarities to technologies in northeastern Asia, which include both microblades and foliate bifaces.

The date of 8500 B.P. is not impossibly early for the bow and arrow in North America. For example, Amick (1994) could not exclude the possibility of Folsom arrows. Ackerman (2009) reports finding antler spear and arrow heads slotted for microblades, as well as the microblades themselves, at two southwestern Alaskan sites. At one site, they were recovered from deposits dating between ca. 10,400 and 8100 B.P. One slotted arrow point was directly radiocarbon dated at 8740 ± 40 B.P. Ackerman (2009) links his microblades to the late Paleolithic Diukti culture of western Beringia, which includes both microblades and foliate bifaces. As he suggests, the bow and arrow could have been part of this late Paleolithic Beringian technology. If we are not correct about Cascade points, then perhaps Hatwai Eared points indicate a local invention of the bow. They could represent a local application to arrows of the side and corner notching spreading from the Great Basin.

We do not address how the technological changes that we document fit with other developments in the Columbia Plateau over the past 11,000 years. That is well beyond the scope of this article. We have not, for example, explored the full implications of the introduction of Cascade points, which, regardless of the weapon systems they represent, are a major change from Windust points. Commenting on the shift from atlatls to bows and arrows in the American Middle West, Shott suggests that "the economic consequences of the transition are at once subtler and less profound than often supposed" (1993:425). Our data suggest that he may be correct about subtle consequences, at least on the Columbia Plateau. Those consequences appear to have rippled across millennia, perhaps invisibly to the people involved. They also have important theoretical and substantive implications beyond those considered here. In any case, the appearance of Cascade points is contemporary with a regional shift in mobility patterns further toward the forager end of the collector–forager continuum (Ames 1988). The increase in the use of darts in the late Cascade phase corresponds with the spread of large side-notched and corner-notched points from the Great Basin to the Plateau. The widespread presence of arrows in the middle Holocene is contemporary with the appearance of houses, stable residential sites, and what appear to be tethered mobility patterns (Ames 1991; Chatters 1989), while the spike in the relative frequency of darts in the early Harder phase is contemporary with evidence of bison hunting on the Plateau (e.g., Chatters et al. 1995; Lyman 1985, 2004; Schroedl 1973). The late revival of darts could therefore be linked to bison hunting, although Amick (1994) suggests that the bow and arrow were more effective for hunting bison. Evidence of subsequent declining use of darts corresponds with the increasing differentiation between darts and arrows, suggesting that darts were part of a tool kit of very specialized gear, but it is also contemporary with greater logistical and community mobility (e.g., Ames 1991; Chatters 1995; Goodale et al. 2004), food storage (Ames 2000), and wealth (Schulting 1995). Similarly, the appearance of "classic" arrows is also contemporary with these latter changes, increased warfare, and the appearance of large residential aggregations (Chatters 2004). Linking shifting weaponry to these broad trends will be an interesting challenge.

Finally, we address potential questions about the methodology employed here. Our analysis is based on metric data; we pay limited attention to potential sources of patterning and variation resulting from differences in raw materials, lithic techniques, repair, discard, and so forth. These are important lines of evidence and would be especially trenchant if our conclusions relied on a single site sample, on only Hatwai, for example, or a small regional sample. In those instances, we would not have gone forward without developing that evidence. However, as we moved through our metric compilations, and our large samples produced remarkably parallel results despite their differences, we felt we had a strong cable of evidence (Wylie 1989). An alternative conclusion is that the array of equations and thresholds used here are flawed, either because of problems in the original museum samples upon which they are based (e.g., Seeman 1992) or because there are special conditions on the Columbia Plateau (e.g., unusually small dart points) that make them inapplicable regionally, at least before 3000 B.P. Shott (1993, 1997) addresses issues with the museum samples, and we address the question of special conditions above. We began this research agnostic about the efficacy of these methods, but given our strikingly parallel results across multiple samples, we conclude that they work rather well.

Summary and Conclusions

We argue that the bow and arrow were present on the Columbia Plateau in the early Holocene. We think the argument is strong for Cascade points. We demonstrate that the bow and arrow were present on the Columbia Plateau in large numbers no later that 4400 B.P. (5000 cal B.P.). Atlatls and bows and arrows were used in varying frequencies through the Holocene until the bow almost completely replaced the atlatl by 1000 B.P., although darts in very small numbers appear to have persisted into the early modern period.

These results indicate that the bow and arrow and atlatls had very patchy and fluctuating temporal and spatial distributions prior to the final late spread of small arrow points. This pattern is also apparent in the data reviewed by Nassaney and Pyle (1999) for the eastern United States. Our results also show that the history of atlatls and bows in one region cannot necessarily be extrapolated to other regions. Their history on the Plateau differs from their history in the Great Basin. Decisions about when to use which weapon system and to what extent were no doubt very local decisions. Ignorance of the alternative system was certainly not a reason. Much like hunter-gatherers with long fluctuating relationships with farmers yet not themselves adopting agriculture, the mid-Holocene, bow-using people on the Plateau interacted with dart-using groups in the Great Basin (Ames 2000; Ames et al. 1998). The dart revival during the late Harder period on the Plateau also suggests that despite the general greater effectiveness of bows and arrows, they were not always better tools, and their utility varied locally in both time and space. Implicit in our evidence is the strong possibility that in some areas, one or the other weapon system might have gone extinct and subsequently been reintroduced. All of this considered, the most important outcome of this study is the demonstration that the bow and arrow were probably present on the Columbia Plateau before 7000 B.P., they were ubiquitous on the Plateau no later than 4400 B.P., and darts and arrows subsequently had an unexpectedly long and complicated mutual history.

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Notes

1. All dates in the text are uncorrected radiocarbon dates. All radiocarbon date calculations, including pooled means and calibrations, were done with CALIB 5.0.1 (Stuiver et al. 2004) for this article.

2. In Ames 2000 it was stated that Cascade points may be as early as 9000 B.P. at Hatwai. This was an error. As part of this research, the proveniences and contexts of all Hatwai Cascade points were reviewed, and none could be firmly placed in a context dating earlier than 8200 B.P.

3. Unfortunately, we did not take axial length measurements and so cannot calculate Thomas's basal indentation ratio, which is a key attribute for Rosegate points.

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