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Flaked-stone projectile point serration: A controlled experimental study of blade margin design

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ABSTRACT

Why were stone projectile point blade margins serrated in some circumstances and not others? Carefully controlled experiments reported here are used to quantify the effects of this attribute on projectile performance. This research suggests that serration does not substantially alter point performance, and this characteristic may therefore vary independently of function. These results in conjunction with patterning in archeological data suggest that point blade traits including serration served as active symbols of sociocultural group membership in some areas, such as the Phoenix Basin in Southern Arizona.

1. Introduction

Until relatively recently, prehistorians largely analyzed stone projectile points using the assumption that patterns they could measure among artifacts were a reflection of differences among sociocultural groups (Mason, 1894:655; Whittaker, 1994:260–268). Little attention was paid to quantifying functional characteristics of projectile technology, and the role that performance plays in morphological variation. Furthermore, with the exception of studies that attempted to replicate prehistoric technology, few carefully controlled experiments were conducted using stone projectile points. However, archeologists are now increasingly employing controlled experiments to test stone point performance (Bergman and Newcomer, 1983; Cheshier and Kelly, 2006; Fauvelle et al., 2012; Frison, 1989; Hunzicker, 2008; Iovita et al., 2014; Lipo et al., 2012; Loendorf et al., in press; Shea et al. 2001, 2002; Sisk and Shea, 2009; Tomka, 2013; Waguespack et al., 2009; Wilkins et al., 2014). Previous researchers have also largely employed typological approaches to study variation, and distinctive characteristics such as serration of the blade margin are commonly allowed to cross-cut categories in classification systems. Research presented here, instead, analyzes serration data independently of typological categories through the collection of controlled experimental data.

Considerable temporal and spatial variability exists in the incidence of projectile point blade serration in North America. However, little work has been done on this subject, and it is unclear if this practice was predominantly done for functional reasons or other purposes. Hoffman (1997) is one of the researchers who have considered this variable, and he concluded that the prehistoric inhabitants of southern Arizona used projectile point blade margin treatment including serration to intentionally signal group affiliations. Hoffman (1997:95) recognized that the shaft and fletching were the most visible portions of arrows, and therefore these elements "were commonly decorated or designed to reflect individual ownership or tribal affiliation" (see also Mason, 1894:662; VanPool and O'Brien, 2013). He, however, focused on points because data from the shafts are not available. He argued that because the haft element was not visible when the points were used, the blade margins were the most visible aspect and therefore are the most likely to exhibit intentional expressions of cultural affiliation.

Characteristics employed as active symbols of social group membership are generally associated with highly visible artifacts used in public contexts (Carr, 1995; Hodder, 1982; Wobst, 1977). Small stone points would seem to fit this definition poorly; however, these artifacts were used in warfare, which is a public setting that is possibly the primary context of interaction for some social groups. Although small points may not have been visible from a distance, they were shot at the enemy thereby increasing the proximity of observation for other groups. Furthermore, stone points were designed to detach within wounds (Loendorf et al., in press), leaving behind a potent symbol of the maker's cultural affiliation. Finally, in some circumstances exceptionally large points were produced, which would have been more visible from a distance (e.g., Fig. 1).

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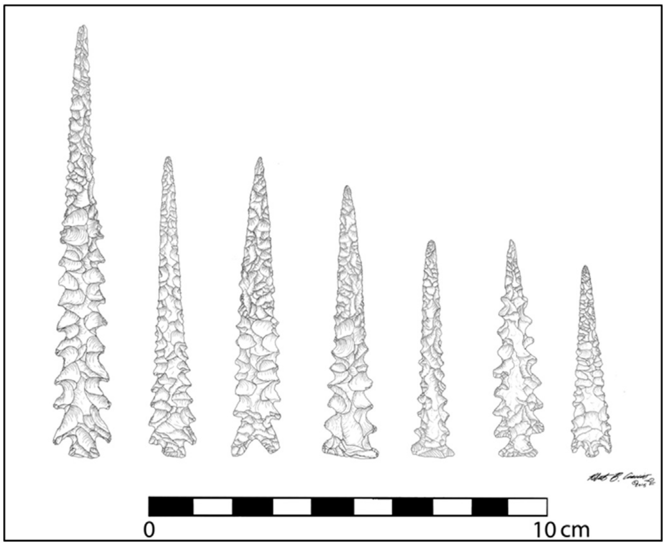

Fig. 1. Artist reconstruction of points collected from Snaketown, by Robert Ciaccio following Haury (1976) and Sayles (1938) (outlines are exact, flaked-scars are approximated).

Although some analysts have argued that serration was done for functional purposes (e.g., Zier, 1978), patterning in the distribution and nature of serrated points suggests the technique may have been done for symbolic reasons in some circumstances. For example, Haury (1976:297) argued that the elaborate serrated points from Snaketown were too exceptionally large and fragile to have been functional (see also Sliva, 2010). As will be discussed further below, similarly large and elaborate points are rare even within the immediate vicinity of Snaketown (Loendorf and Rice, 2004; Loendorf, 2012; Marshall, 2001). Other researchers have also noted variation in the incidence of serration within the Southwest, including Sliva (2006:60) who argued that while serrated points were common during the pre-Classic Hohokam sequence (AD 600–1150), "serrated Puebloan points are rare in any time period".

Archeologists have also recorded patterning in projectile point serration data from other regions. For example, Christenson (1977) found that the incidence of the practice differed over time in the Midwest, and researchers have noted the elaborate nature and spatially restricted distribution of serrated points in California (Johnson, 1940; Hester and Heizer, 1973). As a final example, researchers have suggested that patterning among the sometimes elaborately serrated and hypertrophic points found in caches at some Mississippian sites suggests these artifacts served as conspicuous symbols of involvement in the Cahokian social system (Emerson and Hughes, 2000; Pauketat and Koldehoff, 2002:84–85).

In addition to the exceptionally large points and contextual patterning, there is also ethnographic evidence for the ritual significance placed on projectile points, and their use in ceremonies and other non-mundane activities (Loendorf, 2012; Sedig, 2014). For example, McGee (1898) observed that the Tohono O'odham carried Apache arrow points as talismans in battle, and the Akimel O'odham deposited arrows as offerings at shrines located away from their villages (Russell, 1908:255). Supernatural properties were widely attributed to arrowheads, and they were also used in certain curing ceremonies (Bourke, 1892:468–492; Lumholtz, 1912; Sedig, 2014; Wilson, 1899:849).

2. Stone point experiment materials and methods

Three fundamental aspects of performance were quantified (Christenson, 1997; Cotterell and Kamminga 1992; Loendorf, 2012; Shott, 1993; Vanpool, 2003; Wilkins et al., 2014): 1) Accuracy; this factor was measured by the distance between the impact location and the point of aim. 2) Wound size; in this analysis projectile sectional area was held constant, and wound size was quantified based on the depth of penetration. Because the draw weight and length were fixed, the potential energy of the bow was held constant, and arrow weight was used to normalize the penetration data. 3) Point durability; breakage and point detachment patterns were used to assess this variable.

To control as many sources of variation as possible, commercially manufactured solid wooden arrows were employed. The arrows were matched into pairs, and a serrated point was placed on one and an unserrated point was attached to the other. An arrow with a sharpened tip and no stone point was employed as a control throughout the experiments.

In order to control for differences in manufacturing technique and material, all points were made by Daniel Dybowski from Government Mountain obsidian. The points approximated the average size of arrow tips in a large collection of artifacts from the Gila River Indian Community (GRIC; Loendorf and Rice, 2004). A total of 24 isosceles triangular points were made, half of which were randomly chosen and serrated, while the other half were left without serrations. The experimental points all have straight blade margins and straight bases. Although there is minor variance, serrated and unserrated points are not statistically significantly different (Table 1).

All points were hafted as securely as possible using approximately 500-mm of 2-mm wide artificial sinew, and no adhesives were employed. To minimize shot-to-shot variability, all projectiles were fired using a fixed stand that maintained a uniform draw length and point of aim (Fig. 2). All arrows were fired using a recurve bow with a 14-kg draw weight, and a 47-cm draw length.

A variety of uniform target media were employed, including elastic (foam, plastic, and ballistics gel) and more inelastic materials (rawhide, and polymethylmethacrylate or PMMA). The foam targets consisted of 5 layers of 70-mm thick polystyrene that were covered with a layer of 5-mm thick foam core poster board, and 2 layers of 0.15-mm thick plastic. The ballistic gel was made by Clear Ballistics ™, and this material matches the density of human tissue and meets FBI protocols for projectile testing. To examine impacts with less elastic materials, rawhide with three different thicknesses (0.2 mm, 2.6 mm, and 3 mm) was placed in front of ballistics gel. Points were also fired at 20 cm of polystyrene covering a sheet of PMMA.

In order to limit environmental variability (e.g., wind, temperature) the experiments were conducted indoors. As a result of the limited space it was necessary to place the targets at an average of 2.3 m from the bow string. The first arrow shot lacked a stone point, and this projectile was employed to establish the point of aim. Arrows with serrated and unserrated points were then alternately fired until all points detached, or were broken, or the experimental run ended. To help limit intra-run variation, the control arrow was fired approximately every tenth shot.

Table 1
Experimental point metric attributes.

	N	Minimum	Maximum	Mean	Std. deviation
Unserrated					
Length (mm)	12	13.90	20.95	19.23	1.89
Max thick (mm)	12	3.00	3.95	3.36	0.29
Base width (mm)	12	8.00	12.00	9.27	0.97
Weight (g)	12	0.33	0.74	0.61	0.10
Serrated					
Length (mm)	12	17.97	21.16	19.73	1.04
Max thick (mm)	12	2.73	3.88	3.43	0.38
Base width (mm)	12	8.00	10.00	9.25	0.89
Weight (g)	12	0.50	0.67	0.60	0.06

Fig. 2. Mike Withrow (left) and Ashley Bitowf (right) collecting experimental data.

3. Stone point experiment results

The following sections summarize data for a total of 359 arrow impacts. These data were collected over the course of 17 days between January 21st, 2015 and March 4th, 2015.

3.1. Accuracy

Fig. 3 shows boxplots of the distance between the point of aim and where the arrow impacted (Table 2). The two distributions are not significantly different (unpaired t-test: $t = 0.88$, $df = 299$, $p = 0.38$). However, given the proximity of the target, there is considerable variation in these data. Furthermore, the arrow that lacked a stone point was used to establish the point of aim, and the inconsistency in these data indicates poor precision. Consequently, it is possible that this variance exceeds any accuracy difference between designs. Therefore, an arrow was fitted with a serrated point and fired at the target 10 times. This tip was then replaced with an unserrated point and the same arrow was fired another 10 times. This arrow was more accurate and hit within an average of 2.4 cm from the aim point, with a standard deviation of 1.3 cm. The arrow performed similarly with both points, and the datasets are not significantly different (unpaired t-test: $t = -0.04$, $df = 18$, $p = 0.97$). These data show that the presence of serrations on the blade margin did not significantly alter the accuracy of projectiles.

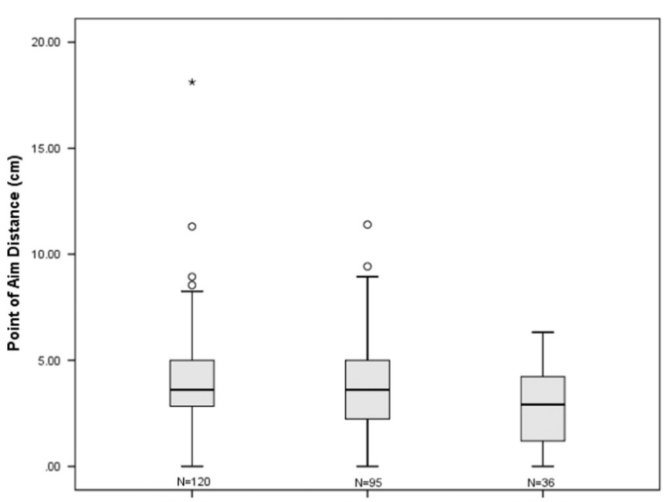

Fig. 3. Distance from the point of aim for serrated, unserrated, and untipped projectiles.

3.2. Wound size

Within the ballistics gel, serrated points penetrated slightly deeper on average (Fig. 4; Table 3), but this variation is not statistically significant at the 95% confidence interval (unpaired t-test: $t = -1.84$, $df = 50$, $p = 0.07$). The possibility that serrated points penetrated deeper may result from the fact that the irregularities in the blade margin provided locations where the sinew was recessed from the outer edge, thereby reducing friction. This variation, however, is slight, and would not occur if the points were attached using only adhesives, or if the ligatures were not wrapped around the blade. These data show that serration did not substantially affect point penetration, and this characteristic may therefore be free to vary independently of function.

3.3. Durability

Fig. 5 shows the number of times arrows were fired before the points detached for all target types. Both serrated and unserrated points have a large range of variation, and they are not significantly different

Table 2
Accuracy for arrows with serrated points, unserrated points, and no stone points.

	N	Minimum	Maximum	Mean	Std. deviation
Unserrated					
Aim distance (cm)	120	0	18.1	4.1	2.1
Serrated					
Aim distance (cm)	95	0	11.4	3.9	2.0
No stone point					
Aim distance (cm)	36	0	6.3	2.9	1.8

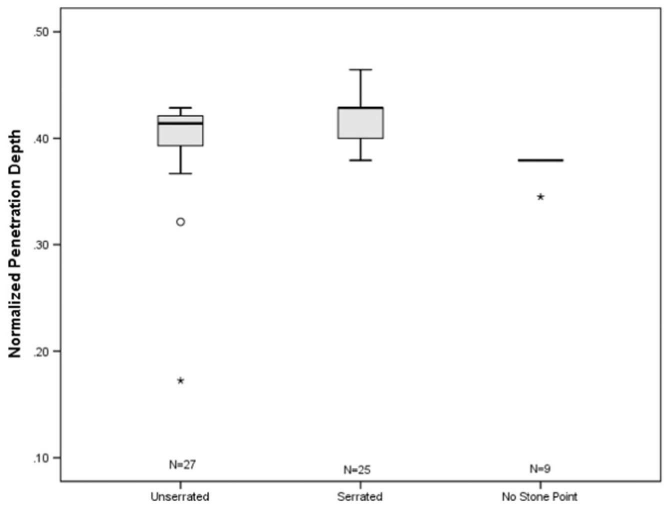

Fig. 4. Normalized penetration data for ballistics gel by point tip type.

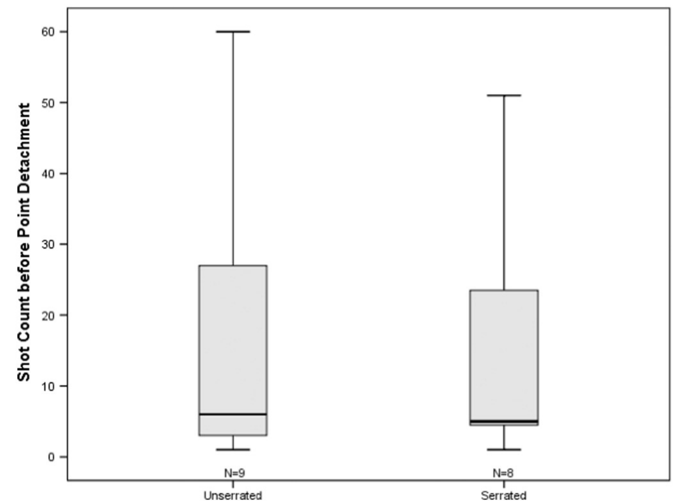

Fig. 5. Shot count before point detachment by tip type.

(unpaired t-test: t = −.42, df = 33, p = 0.68). In this analysis, all points were attached as securely as possible using only ligatures, but research suggests that points designed for use in warfare may have been intentionally loosely secured to arrows (Loendorf et al., in press). Consequently, the attachment method employed in the experiments may differ from actual methods, but the experimental results still suggest that serration did not significantly alter point attachment rates.

Overall, breakage patterns for serrated and unserrated points are similar (Table 4), and do not significantly differ (chi-square = 0.17, probability = 0.67). Not surprisingly, only one point had minor damage in the foam target impacts (N = 232), and no points were damaged in the ballistics gel (N = 52), although one serrated point did detach. Similarly, no points detached or were broken when impacting the ballistics gel covered with 0.2 mm of rawhide (N = 20). However, points suffered high damage rates in the 2.6 and 3 mm rawhide impacts (Table 5). Although serrated points had slightly higher failure rates, the difference is not statistically significant (Fisher's Exact p = 0.62).

Two serrated and two unserrated points were fired at PMMA that was covered with polystyrene foam, and all of them suffered catastrophic failures (Fig. 6). The severe damage to the points may in part result from the lack of adhesives, which would help transfer the impact to the shaft and improve durability (Fauvelle et al., 2012). The low fracture toughness of obsidian also contributed to the severe damage, and these results show that obsidian points attached without adhesives would not be employed in circumstances where high durability was necessary for successful performance.

4. Archeological data discussion

The preceding analyses have presented empirical evidence that serration does not substantially alter point performance, and may therefore vary independently of function. As such, social segments could potentially have employed this characteristic as an intentional symbol of group membership. If this was the case, then temporal and spatial variation in point margin treatment can be employed to assess interactions among prehistoric and historic sociocultural groups.

Points with serrated blades are unequally distributed within the Hohokam region of southern Arizona, and variation among adjacent locations suggests that the practice was not a response to environmental constraints (Hoffman, 1997; Loendorf, 2012; Marshall, 2001; Sliva, 2006). For example, GRIC data show that serration frequencies vary among different locations and over time along the middle Gila River (Table 6). Ethnohistorical descriptions and archeological data both indicate that Casa Blanca is the core area of Akimel O'odham historic period habitation in the Phoenix Basin (Loendorf, 2012, 2014; Wilson, 2014). This region differs from nearby areas and only 6% of all Casa Blanca points were serrated, while over a third of points from all other locations had this form of edge treatment (Yates corrected Chi-Square = 45.4, p < 0.001). This total includes artifacts that were classified as Middle Archaic through historic period remains (Fig. 7). Furthermore, as shown in Fig. 8, the overall proportion of serrated points tends to increase with distance from Casa Blanca.

The lowest incidence of serration within Casa Blanca occurs during the historic period, a time when almost 50% of the points from elsewhere in the community were serrated (Yates corrected Chi-Square = 40.06, p < 0.001). Both ethnohistorical and archeological data document the arrival of immigrants who settled on the margins of the Casa Blanca area during the historic period, and some of these people came from regions where serration is prevalent, such as the San Pedro river (Loendorf, 2014; Loendorf et al., 2013; Seymour, 2011; Vint, 2005; Wilson, 2014).

These data therefore suggest that long-term prehistoric traditions in the Casa Blanca area were maintained through time into the historic period. This continuation of practices shows cultural continuity over a

Table 3
Arrow penetration within ballistic gel by tip type.

	N	Minimum	Maximum	Mean	Std. deviation
Unserrated					
Penetration depth (cm)	27	5.00	12.00	11.30	1.40
Normalized penetration	27	0.17	0.43	0.40	0.05
Serrated					
Penetration depth (cm)	25	11.00	14.00	12.20	0.91
Normalized penetration	25	0.38	0.46	0.42	0.02
No stone point					
Penetration depth (cm)	9	10.00	11.00	10.88	0.35
	9	0.34	0.38	0.38	0.01
Normalized penetration					

Table 4
Point breakage patterns for serrated and unserrated points.

Point break	No	Yes	Total
Unserrated	162	5	167
Serrated	149	7	156
Total	311	12	323

Table 5
Point breakage patterns for serrated and unserrated points in 2.6 and 3 mm rawhide.

Point break	No	Yes	Total
Unserrated	5	3	8
Serrated	3	4	7
Total	8	7	15

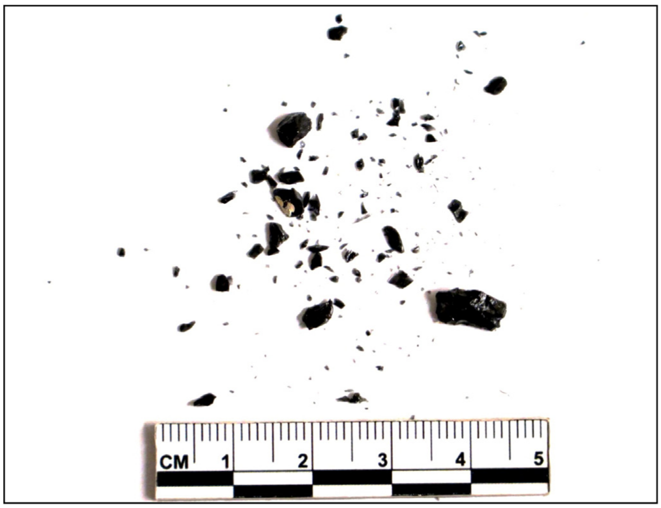

Fig. 6. All fragments that were collected from a point that impacted PMMA.

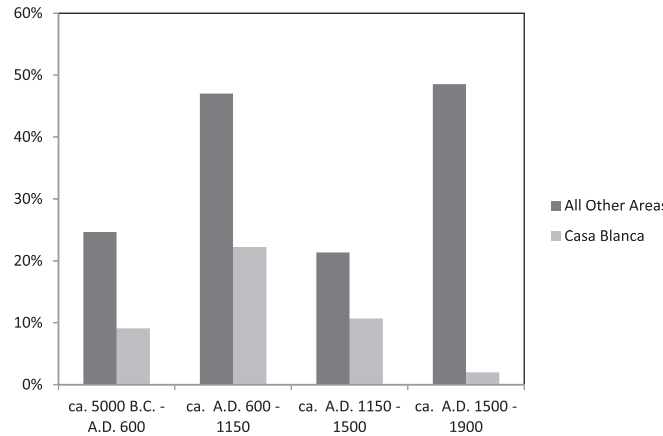

Fig. 7. Proportion of serrated points by time period for the P-MIP survey collection.

considerable time period, and suggests that the historic inhabitants (i.e., Akimel O'odham) are the direct descendants of the prehistoric populations (e.g., Hohokam). At the same time, the temporal and spatial variability in serration data suggest that different social segments lived in the Phoenix Basin, and the use of coercive force was not highly integrated across the region.

5. Conclusions

Serration of the blade margins did not significantly alter the accuracy, wound size, or durability of points under the experimental conditions employed in this study. Although serrated points did tend to penetrate slightly deeper and it is possible that this characteristic may affect other aspects of performance, no substantial differences were measured. These results suggest that this attribute is less constrained by performance requirements, and therefore may have varied independently of point function.

The experimental results and archeological data both suggest that sociocultural groups such as the Akimel O'odham and their ancestors employed point morphological characteristics as active symbols of social affiliation. Analyses of these data within southern Arizona suggest that regional prehistoric and historic populations were not closely politically unified (Hoffman, 1997; Loendorf et al., 2013; Simon and Gosser, 2001). Concurrently, long-term patterning in point design suggests cultural continuity over a remarkable period of time within locations such as the Casa Blanca area along the middle Gila River.

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Table 6
All projectile points by serration presence and location within the Gila River Indian Community, P-MIP Survey Collection.
(Loendorf and Rice, 2004).

Site group	Serration absence/presence by time period														
	ca. 5000 B.C.–A.D. 600			ca. A.D. 600–1150			ca. A.D. 1150–1500			ca. A.D. 1500–1900			Total		
	−	+	%	−	+	%	−	+	%	−	+	%	−	+	%
N. Blackwater		–			–		0	1	100%	0	1	100%	0	2	100%
West End	2	1	33%	6	8	57%	3	2	40%		–		11	11	50%
Lone Butte	4	2	33%	2	3	60%	5	3	38%	2	1	33%	13	9	41%
Santan	2	3	60%	1	4	80%	6	0	0%	3	0	0%	12	7	37%
Snaketown	28	12	30%	35	25	42%	43	9	17%	12	20	63%	118	66	36%
Borderlands	55	25	31%	2	2	50%	3	2	40%	4	0	0%	64	29	31%
Santa Cruz	27	2	7%	4	4	50%	17	3	15%	19	17	47%	67	26	28%
Blackwater	33	7	18%	1	0	0%	2	2	50%	12	8	40%	48	17	26%
Sacaton	8	0	0%	2	1	33%	2	0	0%	1	3	75%	13	4	24%
Casa Blanca	20	2	9%	7	2	22%	25	3	11%	98	2	2%	150	9	6%
Total	179	54	23%	60	49	45%	106	25	19%	151	52	26%	496	180	27%

*Excludes isolated occurrences, and unfinished points (preforms).

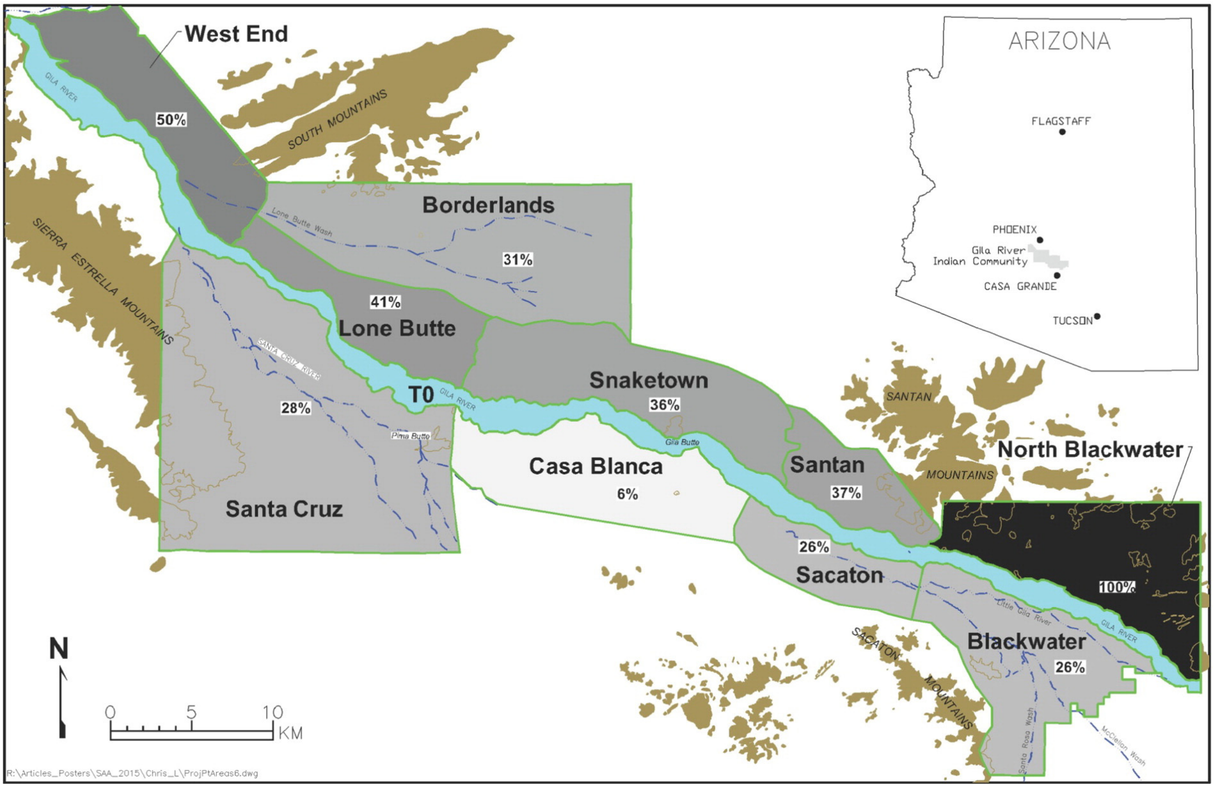

Fig. 8. Proportions of serrated points by study unit, P-MIP collection. Units shaded based on serration proportions, with black being the greatest. Percentages are the serrated proportions.

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