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An Experimental Study of Projectile Point Fracture Patterns

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EFFORTS to reconstruct culture histories in the Great Basin have relied heavily upon projectile point typology to provide a general chronological framework (Heizer and Baumhoff 1961; Clewlow 1967; Heizer and Hester 1978; Thomas 1981). Traditionally, classificatory systems have been based on projectile point morphology and have employed such variables as length, width, thickness, and neck width, among others. While earlier systems were somewhat intuitive, researchers recently have employed more formalized typologies based on sometimes complex metric data (Holmer 1978; Thomas 1981). In his Monitor Valley projectile point typology, Thomas (1981) eliminated many metric variables that he believed lacked temporal sensitivity and relied primarily upon attributes identified as being "robust" (Thomas 1981:15). In other words, he employed only variables that could statistically differentiate one morphological type from another. These variables included proximal and distal shoulder angle, notch opening index, basal indention ratio, maximum blade width position, and basal width/maximum width ratio (Thomas 1981:14).

While these studies provide a basis upon which culture histories are reconstructed, they often require complete or nearly complete specimens. Therefore, they do not provide a means of using the vast amount of information available through the study of projectile point fragments that may not lend themselves to typological comparison.

Projectile point fragments can represent a significant percentage or even exceed the number of diagnostic specimens recovered at a given site (Aikens 1970:34; Ames et al. 1981:79; Plew 1981:146). This paper is an effort to contribute to our ability to obtain useful information from projectile point fragments. Specifically, we attempt to present a means of determining causes of projectile point damage and particularly to differentiate use-related breakage from manufacturing-induced breakage. This determination may ultimately offer additional data relative to site function, identification of task-specific loci within sites, and other avenues of inquiry. Toward that end, we propose descriptive terminology and present data from an experimental study involving the manufacture, use, and breakage of a specific Great Basin projectile point type.

The Elko Corner-notched dart point type was selected for this project because other researchers experimenting with projectile point breakage have used comparable corner-notched points in their studies (Flenniken 1985; Flenniken and Raymond 1985; Towner and Warburton 1985), and the comparison of breakage results is possible where similar point types are employed. Since a major goal of this study was the comparison of breakage patterns resulting from use as well as from manufacture, we intentionally selected a point type with morphological attributes that would encourage as much manufacturing damage as possible. Previous experience suggested that manufacturing breakage would occur most frequently during the notching sequence, therefore eliminating the choice of stemmed or other unnotched varieties.

PROCEDURE

Thirty-nine replicas of an Elko Corner-notched point from Nahas Cave in the Owyhee Uplands of southern Idaho (Plew 1985: 164, Fig. 31e) were manufactured for this study. This specific point was selected because it possesses relatively narrow notch-widths and prior experience had suggested that the manufacture of points with narrow notches usually produces a higher rate of damage due to limited space between the notching tool and the sides of the notch. The replicated projectile points were made of obsidians from three sources in the western United States (Table 1). With the limited sample size, the variables of raw material hardness and toughness largely were eliminated by limiting the replications to specimens made of obsidian.

The replicas were each manufactured from percussion flakes using copper-tipped pressure flakers. One knapper held these flake-blanks in the palm of the hand (all replicas preceded by "1985" in Figs. 1, 3, and 6); the other used a finger-holding technique (all replicas preceded by a "T" in Figs. 1, 3, and 6). For notching, both knappers used copper tools with one working edge, using an edge-of-tool technique previously described by Titmus (1985:254-255).

Nine of the replicated points were damaged prior to completion; the remaining 30 were successfully completed and prepared for use-breakage experiments (Fig. 1). Each of the 30 successfully completed points was hafted into hardwood foreshafts 18.0 cm. in length and 1.0 cm. in diameter. The haft was prepared by cutting a groove 10-12 mm. deep into the foreshaft, and the point was then inset with a mastic prepared from pine pitch and charcoal. Once the mastic had set, elk leg sinew was added to seize the foreshaft tightly to the point (Fig. 2). Foreshaft size and haft configuration were based on comparable specimens from Danger

Table 1
REPLICATED SPECIMENS

Number	Knapper	Material Source	Size in cm.
T-1	Titmus	Glass Buttes, OR	4.25 x 2.33 x 0.50
T-2	Titmus	Glass Buttes, OR	4.12 x 2.42 x 0.43
T-3	Titmus	Brown's Bench, ID	4.10 x 2.34 x 0.44
T-4	Titmus	Glass Buttes, OR	4.53 x 2.58 x 0.45
T-5	Titmus	Glass Buttes, OR	4.33 x 2.41 x 0.47
T-6	Titmus	Glass Buttes, OR	4.46 x 2.62 x 0.37
T-7	Titmus	Glass Buttes, OR	4.53 x 2.57 x 0.51
T-8	Titmus	Brown's Bench, ID	4.38 x 2.60 x 0.45
T-9	Titmus	Brown's Bench, ID	4.35 x 2.58 x 0.48
T-10	Titmus	Brown's Bench, ID	4.27 x 2.15 x 0.58
T-11	Titmus	Brown's Bench, ID	4.42 x 2.28 x 0.53
T-12	Titmus	Glass Buttes, OR	4.53 x 2.63 x 0.48
T-13	Titmus	Glass Buttes, OR	4.34 x 2.56 x 0.48
T-14	Titmus	Brown's Bench, ID	4.20 x 2.48 x 0.52
T-15	Titmus	Glass Buttes, OR	4.41 x 2.45 x 0.43
T-16	Titmus	Glass Buttes, OR	4.49 x 2.52 x 0.51
T-17	Titmus	Brown's Bench, ID	4.17 x 2.25 x 0.53
T-18	Titmus	Glass Buttes, OR	4.53 x 2.34 x 0.55
T-19	Titmus	Brown's Bench, ID	4.00 x 2.34 x 0.42
T-20	Titmus	Brown's Bench, ID	4.10 x 2.27 x 0.45
1985-108	Woods	Brown's Bench, ID	4.23 x 2.28 x 0.62
1985-109	Woods	Brown's Bench, ID	4.24 x 2.55 x 0.50
1985-110	Woods	Glass Buttes, OR	4.15 x 2.61 x 0.52
1985-111	Woods	Glass Buttes, OR	4.10 x 2.56 x 0.58
1985-112	Woods	Glass Buttes, OR	4.22 x 2.44 x 0.46
1985-113	Woods	Brown's Bench, ID	4.06 x 2.47 x 0.50
1985-114	Woods	Brown's Bench, ID	4.16 x 2.41 x 0.60
1985-115	Woods	Glass Buttes, OR	4.32 x 2.51 x 0.50
1985-116	Woods	Glass Buttes, OR	4.24 x 2.45 x 0.56
1985-117	Woods	Brown's Bench, ID	4.02 x 2.37 x 0.58
1985-118	Woods	Glass Buttes, OR	4.25 x 2.56 x 0.59
1985-119	Woods	Centennial Mtn., ID	4.14 x 2.32 x 0.60
1985-120	Woods	Centennial Mtn., ID	4.24 x 2.61 x 0.52
1985-121	Woods	Glass Buttes, OR	4.30 x 2.52 x 0.52
1985-122	Woods	Glass Buttes, OR	4.14 x 2.31 x 0.47
1985-123	Woods	Glass Buttes, OR	4.31 x 2.28 x 0.56
1985-124	Woods	Glass Buttes, OR	4.24 x 2.40 x 0.47
1985-125	Woods	Glass Buttes, OR	4.29 x 2.30 x 0.50
1985-126	Woods	Glass Buttes, OR	4.21 x 2.37 x 0.56

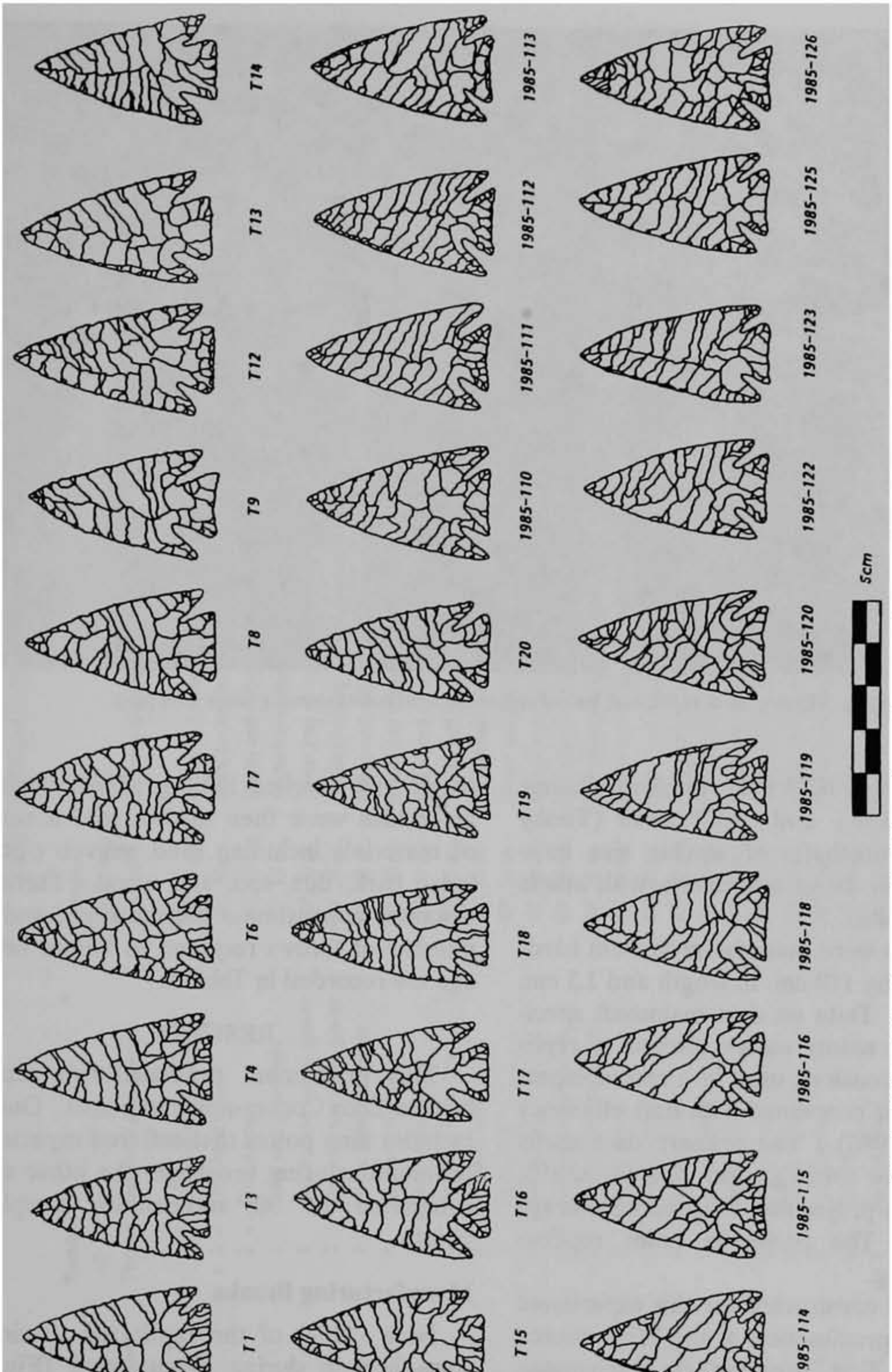

Fig. 1. Thirty Elko Corner-notched dart point replicas manufactured for use-breakage experiments.

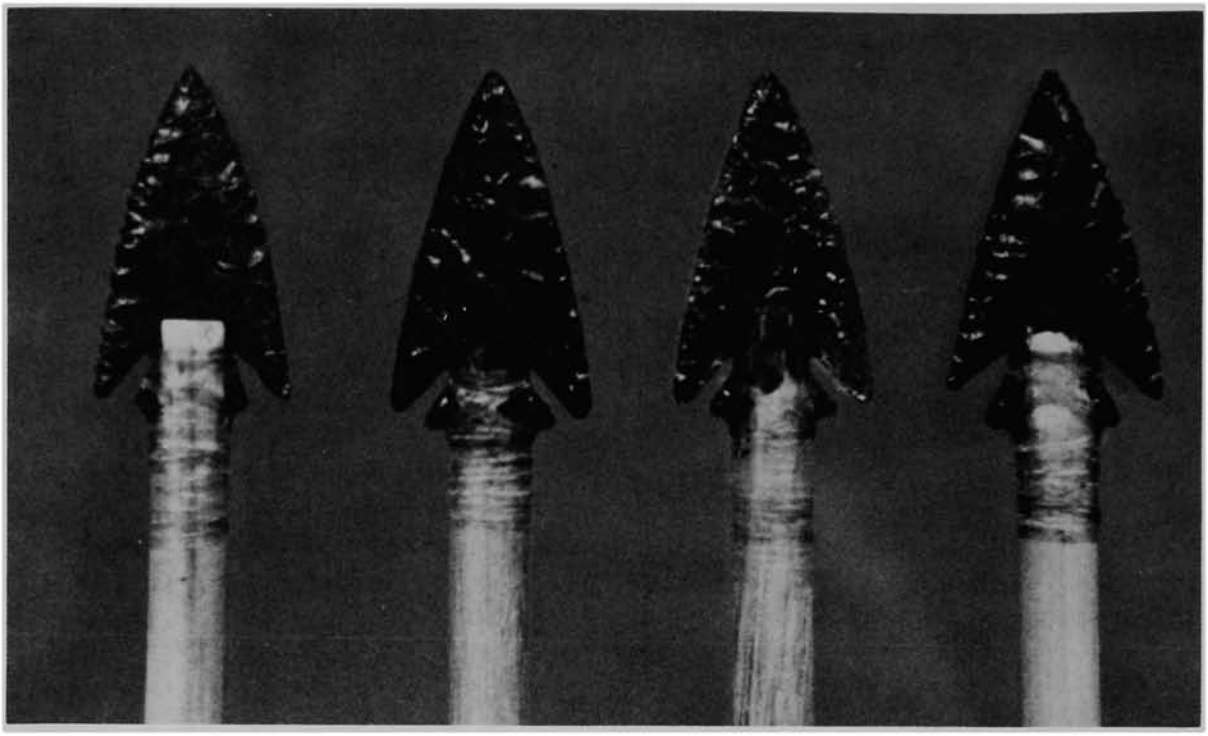

Fig. 2. Examples of replicated, hafted corner-notched points showing sinew wrapping.

Cave (Jennings 1957:190), Swallow Shelter (Dalley 1976:58), and "NC" Cave (Tuohy 1982: 85); foreshafts of similar size have been found in direct association with atlatls at the latter site.

Two darts were manufactured from hardwood doweling 119 cm. in length and 1.3 cm. in diameter. Data on dart mainshaft specifications are scanty so we elected to replicate dart dimensions used in a recent experimental paper concerned with dart efficiency (Raymond 1986). The primary dart shafts each weighed 94.6 g. and the foreshafts, excluding the projectiles, weighed an average of 6.1 g. The projectile point replicas averaged 3.9 g.

The atlatl constructed for this experiment is a close approximation of the Winnemucca Lake atlatl first reported by Harrington (1959) and later illustrated by Hester (1974: 61). The replicated atlatl was 58.0 cm. in length and weighed 155.6 g. The completed projectiles were then thrown into a variety of materials including sand, gravel, cinders, loose bark, dirt, sod, and wood. Throwing distance, approximate impact angle, and the number of throws required to induce breakage are recorded in Table 2.

RESULTS

This experiment produced two sets of broken Elko Corner-notched points. One set includes nine points that suffered experimental manufacturing breakage; the other set is comprised of 30 successfully completed points.

Manufacturing Breaks

Nine (23%) of the replicated specimens were broken during manufacture (Fig. 3). Various kinds of breaks were produced, but the most common involved the removal of a

Table 2
EXPERIMENTAL USE BREAKAGE RESULTS

Number	Number of Throws	Impacted Materials	Impact Angle and Distance	Damage Description
T-1	1	Loose cinders and dirt	20°, 20 m.	Distal end collapse, rt. lat. margin burination, left barb broken, neck broken.
T-3	1	Dry, hard sod	25°, 30 m.	Neck broken laterally.
T-4	1	Pine stump	80°, 10 m.	Distal end collapse, neck broken laterally with intersecting longitudinal break from base.
T-6	1	Sand and gravel mix	20°, 15 m.	Slight burination at distal end, rt. lat. margin crushing, rt. barb broken, neck broken laterally.
T-7	1	Dry sod over sand, gravel	20°, 10 m.	Distal end collapse, rt. and left lat. margin crushing, rt. barb broken.
T-8	2	Dry sod over sand, gravel	20°, 25 m.	Slight crushing at distal end, rt. lat. margin crushing, rt. barb broken, neck broken laterally.
T-9	1	Loose bark and gravel	20°, 25 m.	Distal end collapse and abrasion, both barbs broken, neck broken laterally.
T-12	8	Wet sod over sand	20°, 30 m.	Distal end missing, neck broken laterally.
T-13	1	Packed, dry dirt	30°, 60 m.	Distal end missing, neck broken laterally.
T-14	1	Brush and into branch	85°, 15 m.	Distal end broken laterally with slight burination.
T-15	2	Dry sod, sand	20°, 35 m.	Neck broken laterally.
T-17	1	Rock wall	90°, 20 m.	Distal and proximal ends missing, severed by reverse hinge fracture.
T-18	1	Pine stump	90°, 10 m.	Distal end collapse, slight burination on left lateral margin.
T-19	1	Live softwood branch	90°, 20 m.	Distal end collapse, longitudinal shear through mid-section, base missing.
T-20	1	Loose gravel into rock	90°, 10 m.	Left lateral margin crushing, neck broken laterally.
1985-110	3	Loose gravel	20°, 10 m.	Distal end missing, base fractured laterally with intersecting longitudinal fracture.
1985-111	1	Loose cinders	20°, 20 m.	Distal end collapse, rt. and left margins heavily abraded with some crushing, both barbs broken.
1985-112	4	Dry sod, sand	20°, 20 m.	Lateral breakage above neck, left barb missing.
1985-113	1	Loose gravel	30°, 10 m.	Distal end collapse, rt. lateral margin crushing, rt. barb missing.
1985-114	5	Loose cinders	20°, 30 m.	Distal end collapse, slight burination on left lat. margin, crushing along rt. lat. margin.
1985-115	1	Dry sod, packed dirt	20°, 30 m.	Neck broken laterally.
1985-116	10	Living willow tree	90°, 5 m.	Distal end missing, burination on left lat. margin, neck fractured diagonally, rt. barb missing.
1985-118	4	Loose gravel	30°, 8 m.	Distal end collapse, burination from secondary impact, left lat. margin crushing, rt. barb missing.
1985-119	1	Rock	90°, 9 m.	Irregular fracture at mid-line followed by secondary burination and distal end crushing.
1985-120	1	Packed gravel	20°, 20 m.	Slight damage to distal end, left barb missing, neck broken laterally, abrasion on both margins.
1985-122	1	Packed gravel	45°, 10 m.	Lateral fracture at mid-section with secondary crushing, left barb missing, abrasion on margins.
1985-123	1	Living willow tree	90°, 10 m.	Distal end collapse, margin crushing on rt. lateral margin near distal end.
1985-125	1	Loose gravel into rock	90°, 10 m.	Diagonal fracture near mid-section.
1985-126	5	Loose soil/gravel and rock	80°, 10 m.	Distal end broken laterally, rt. lat. margin crushing, both barbs missing.

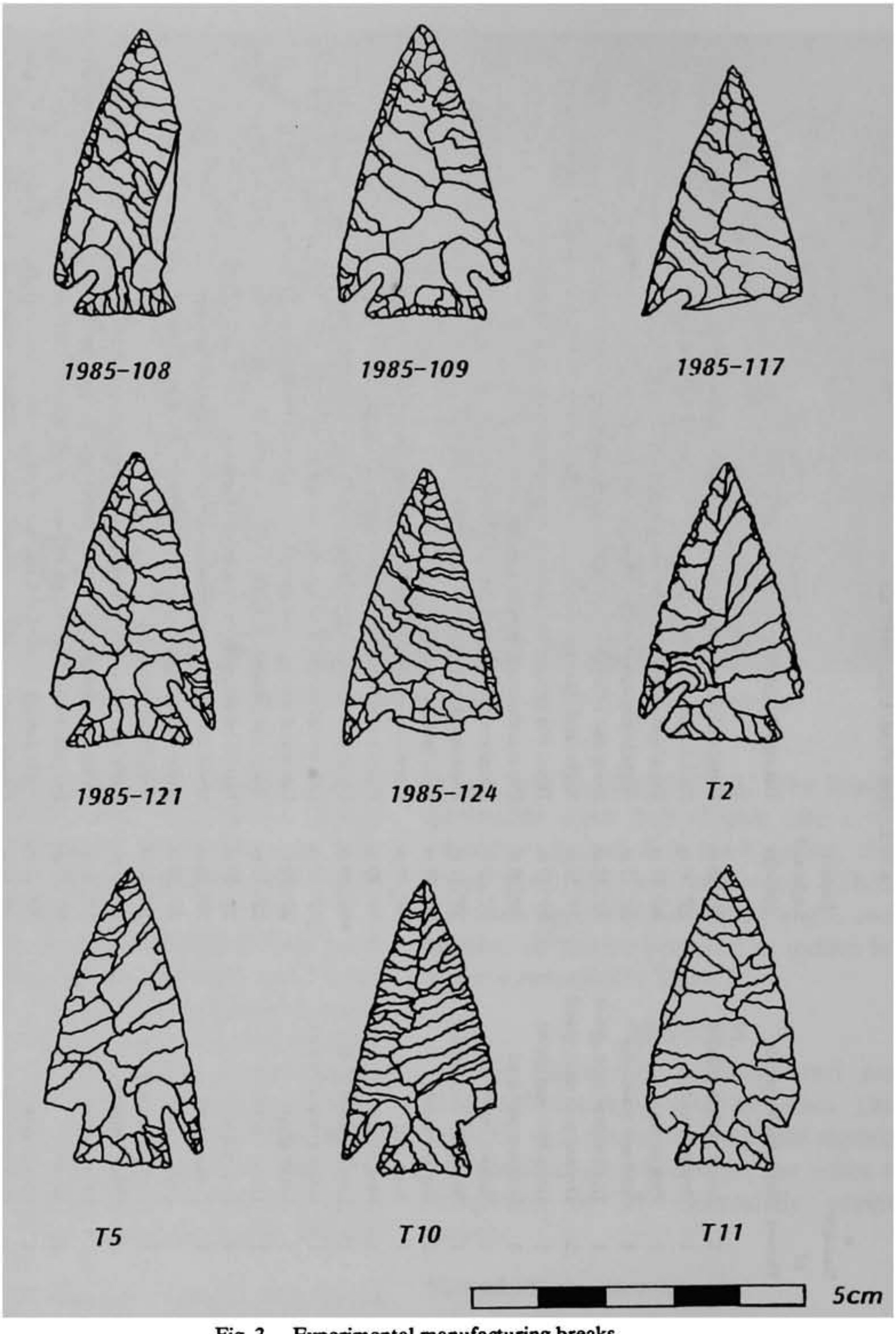

Fig. 3. Experimental manufacturing breaks.

barb as previously described by Titmus (1985:250) who noted

> the tendency of the notching flake, when it is near the margin, to follow the two sides of the notch and detach the sides of the notch above where they intersect the margin.

Four (44%) of the manufacturing breaks are of this kind. Two specimens (1985-117, 1985-124) broke laterally across the neck as a result of incorrect twisting of the notching tool as it was seated on the notch platform. An additional specimen (1985-108) broke longitudinally as a result of the same error. The final two manufacturing breaks (T-5, T-10) were produced from excessive lateral pressure from the knapper's thumb against the fragile barb.

Use Breaks

The remaining 30 (77%) points of the replicated collection were intentionally broken as a result of impact upon a variety of target materials. Results of these efforts at use-breakage are recorded in Table 2. Materials to be impacted were selected in an effort to provide variation in target hardness. Impact distance and angle varied as a result of inconsistent release of the dart, inaccurate throws, dart ricochet, or intuitive selection by the authors. To closely replicate actual hunting conditions, we would ideally have used the hafted replicas in live-animal hunting situations. However, this variable was eliminated due to ethical considerations. Other researchers (Fischer et al. 1984) have used animal carcasses as targets although the utility of data thus generated may be questionable as live, moving targets create different conditions from previously dispatched animals.

Although 21 of the 30 experimentally thrown points (70%) were damaged upon first use, the remainder required multiple throws. Up to 10 throws were required to cause breakage on some specimens. For the entire collection of experimentally produced and broken points, an average of 2.1 throws per point were required to induce breakage.

Five points (16.6%) suffered damage only to the distal end, one (3.3%) suffered damage only to the mid-section, and five (16.6%) suffered damage only to the proximal end. Fifteen (50%) revealed a combination of break locations, and four (13.2%) were unclassifiable as the broken portions of the projectiles were not recovered (Fig. 4).

In addition to the above-noted distinctions in break location, morphological variation of the fractures themselves was noted to result from three basic forces: bending, crushing, and shearing.

Bending. The most common breaks were oriented laterally and were produced as a result of forces exerted perpendicular to the projectile face. Two varieties of bending fractures were identified on the basis of fracture termination. Hinged terminations were most common, although several specimens possessed only a slight lip at the fracture termination. Bending fractures were most commonly located at the neck, and resulted from impact on soft, yielding materials such as sod, but these breaks also resulted from impact on harder, yielding materials such as loose gravel (see Table 2).

Crushing. Fractures resulting from impact on a hard, unyielding surface such as a large boulder or an old, dried pine stump produced another common break best described as crushing. This form of fracture occurred primarily at the distal end, but was also expressed along margins in several instances. Crushing resulted from the removal of an overlapping series of heavily undulating flakes that either terminate on the tool face or leave deep step fractures at the point of impact.

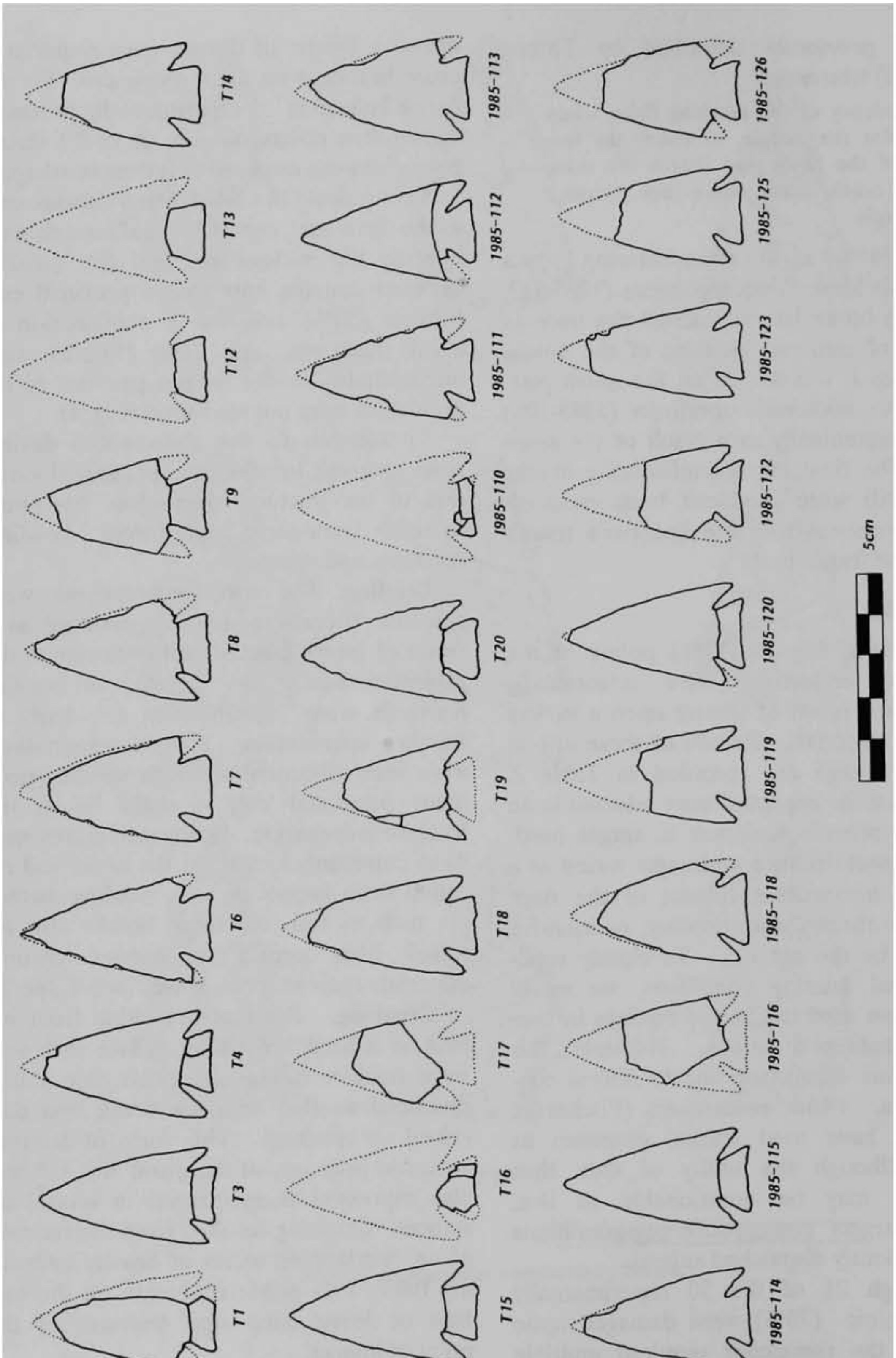

Fig. 4. Experimental breakage patterns produced on replicated corner-notched points.

Some crushing occurred after the projectile was broken by a bending break. This secondary impacting was the result of the momentum of the dart forcing the damaged point into a hard surface. Secondary impacting was most common on specimens thrown at hard but yielding surfaces such as gravel and loose cinders.

Shearing. On projectiles subjected to forces in-line with the long axis of the blade, and in cases where the impacted materials were somewhat yielding, such as live wood, the resulting fractures were primarily oriented longitudinally in the form of what could be termed burinations. These fractures can result from the splitting of the cone of force and leave a flake scar that forms a right angle edge on both faces (Crabtree 1972:48). The majority of barbs broken as a result of impact reveal shearing break features. These differ from bending breaks in that the force is initiated at the margin, as opposed to on the face. Shear breaks seldom reveal a bulb of force or a hinged or lipped termination.

MANUFACTURING AND USE-BREAKAGE COMPARISONS

Comparison of the experimentally produced and damaged points with archaeological specimens shows that the breakage patterns we produced are similar. However, archaeological specimens from several collections we examined possessed a more frequent occurrence of mid-section breaks. Although the cause of this discrepancy is not clear, there was concern that the method of hafting may cause some variation in fracture location. Therefore, a test was devised wherein four additional specimens were replicated (Table 3) and hafted with foreshafts extending to the mid-section of each point (Fig. 5). This was performed to determine if extra support at the neck would alter the location or morphology of the impact breaks.

The four hafted points (Fig. 6) were tested in the same manner as the original replicas (Table 4). Results of this test suggest that lateral breakage at the neck is predominant even if the haft element is more substantial than shown in the archaeological record (cf. Aikens 1970:163; Tuohy 1982:84). It was possible to prevent this type of break on at least one example by application of a liberal amount of adhesive, ensuring good adhesion between the point and foreshaft. On this specimen (Fig. 7, T-22), the point fractured laterally just above the termination of the foreshaft. This suggests that it is possible to reduce breaks at the neck by slight modification of the hafting technique. However, it is important to remember that archaeological examples previously cited do not reveal this modification to the haft.

The most obvious distinction between manufacturing and use-induced breakage is the location of the damage. While use-breakage occurs on all portions of the projectile points, all of the manufacturing breakage in this study is oriented near the notches (Fig. 3). Although results could vary considerably depending on the skill of the knapper, our findings resulted primarily from the reduction sequence employed during this study wherein notching was the final stage and, at least with this point type, the barbs were the most delicate portion of the tool being replicated. It is possible that manufacturing breaks could differ significantly given different reduction sequences. For example, it is possible to produce notches on a preform prior to final pressure flaking. In these instances, manufacturing breaks could vary significantly from those produced during this study.

Table 3
REPLICATED SPECIMENS - POINTS UTILIZING DEEP HAFTS

Number	Knapper	Material Source	Size in cm.
T-21	Titmus	Brown's Bench, ID	3.65 x 2.33 x 0.40
T-22	Titmus	Glass Buttes, OR	4.10 x 2.42 x 0.44
1985-127	Woods	Glass Buttes, OR	4.16 x 2.55 x 0.60
1985-128	Woods	Glass Buttes, OR	4.18 x 2.48 x 0.55

Table 4
EXPERIMENTAL USE BREAKAGE RESULTS: POINTS UTILIZING DEEP HAFTS

Number	Number of Throws	Impacted Material	Impact Angle and Distance	Damage Description
T-21	1	Sod over wet dirt	20°, 20 m.	Neck broken laterally.
T-22	1	Sod over wet dirt	20°, 20 m.	Lateral fracture at mid-section, burination of right barb and crushing to rt. basal margin.
1985-127	6	Sod, then into cinders	80°, 10 m.	Distal end collapse, rt. barb missing, crushing along right lateral margin.
1985-128	1	Sod over wet dirt	45°, 50 m.	Neck broken laterally.

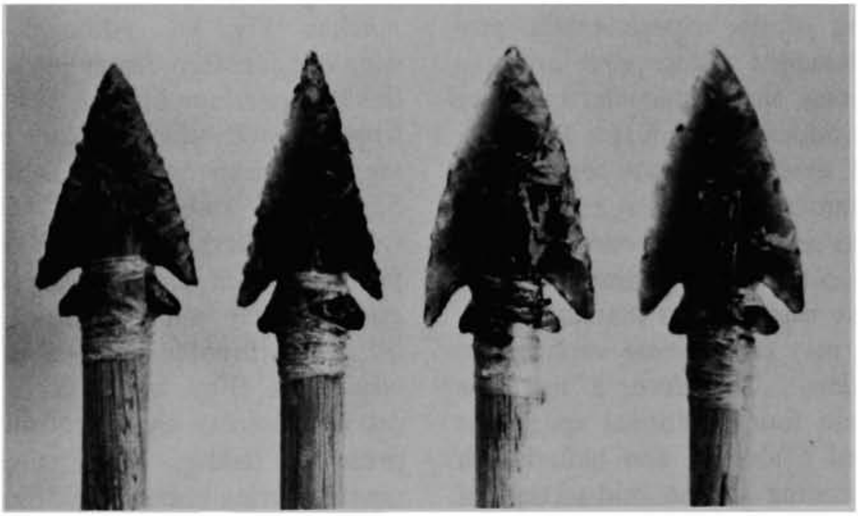

Fig. 5. Corner-notched point replicas with hafting extending to point mid-line.

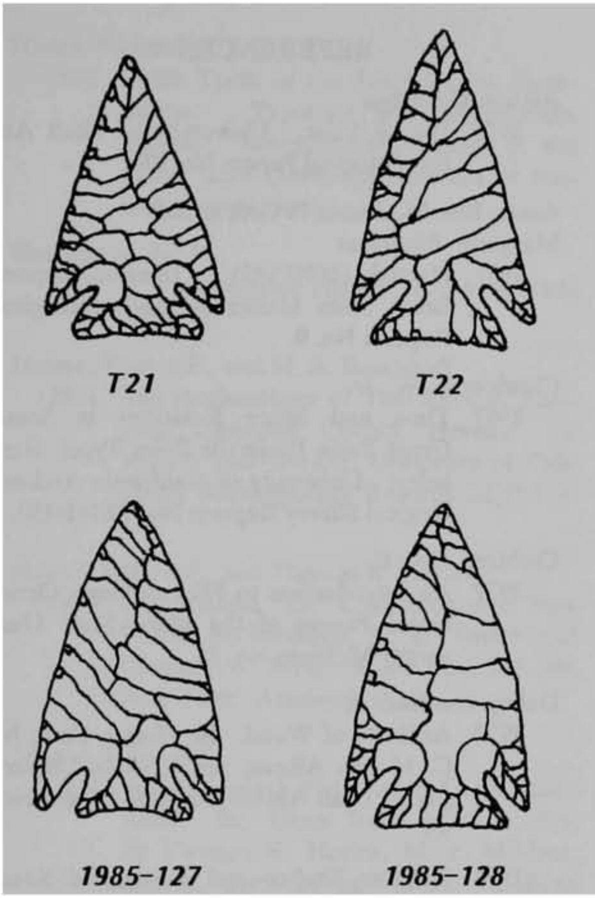

Fig. 6. Four additional corner-notched point replicas prepared for use with deep haft elements.

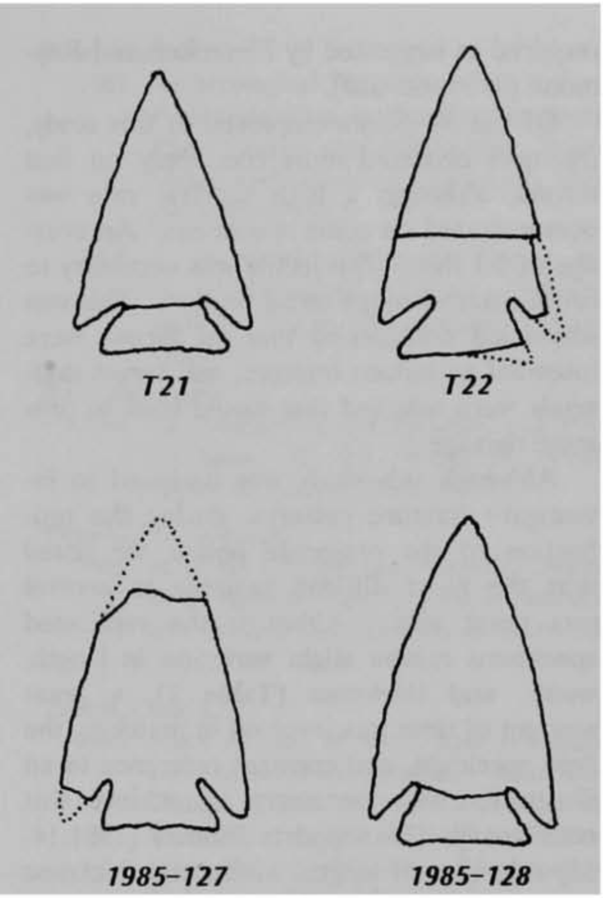

Fig. 7. Breakage patterns on replicas with deep haft elements.

CONCLUSIONS

Results of this fracture pattern study reveal that breakage resulting from manufacture is generally limited to the area of the barbs and possesses a fracture morphology that is diagnostic. About 25% of our attempted replications resulted in manufacturing breaks. However, this frequency will vary depending on the skill of the knapper. Other knappers have produced as many as 47 similar corner-notched points without a single instance of manufacturing damage (Errett Callahan, personal communication).

Breakage from use can occur on any portion of the blade, but most of the damage was a combination of both proximal and distal end damage. Damage to only one end of the blade was equally divided between proximal and distal ends; however, when all fracture types including compound breaks are compared, a much higher percentage of breaks occurred at the proximal end. This contrasts with Thomas' suggestion (1981:14-15) that projectile point damage occurred primarily at the distal end. Based on that conclusion, Thomas relied mostly on basal attributes for establishing typologies. This study has shown that use-modification is primarily expressed at the proximal end. Thus, if reuse were desired, considerable rejuvenation to the typologically diagnostic portion of the projectile point might be required as suggested by Flenniken and Raymond (1986:609-610).

Of the 34 points employed in this study, fractures occurred most commonly on first throws, although a high survival rate was demonstrated on some specimens. An average of 2.1 throws/projectile was necessary to cause macrodamage on all replicas. This was surprising, considering that the throws were intended to induce fracture, and target materials were selected that would tend to promote damage.

Although this study was designed to investigate fracture patterns, during the replication of the projectile points, we noted that the most difficult variable to control was point size. Although the replicated specimens exhibit slight variation in length, width, and thickness (Table 1), a great amount of time was involved in matching the type specimen, and constant reference to an illustration was necessary to achieve this consistency. This supports Thomas' (1981:14-15) rejection of length, width, and thickness as important variables in Great Basin projectile point morphological studies.

Through analysis of breakage patterns on projectile point fragments, it is usually possible to distinguish damage caused during manufacture from damage caused during use. Thus, numerous point fragments that normally are only added to lithic type frequency charts, if included at all in site analysis may take on additional interpretive value. Furthermore, fragments recovered from the landscape as isolated specimens during site survey can profitably be subjected to functional interpretations. It is hoped that the results of this paper will contribute to our understanding of discard behavior and refine our ability to determine site function on the basis of careful scrutiny of the numerous projectile point fragments recovered from Great Basin sites.

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