Burin Manufacture and Utilization: An Experimental Study

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Burins were experimentally manufactured and utilized to differentiate the effects on wear patterns of raw material, method of manufacture, material utilized, and mode of utilization. Differing methods of manufacture and modes of utilization were employed to test the assumed function of burins as being exclusively bone/antler working tools. Results of univariate and multivariate statistical tests are presented along with differentiating characteristics of three methods of manufacture (hard-hammer, soft-hammer, pressure), three types of raw materials (obsidian, basalt, chert), four materials worked (hard and soft wood; dry and soaked bone), and two modes of utilization (graving, scraping).

Introduction

Typological classification of lithic artifacts has traditionally emphasized morphological characteristics in which function was more assumed than hypothesized. Consequently, classifications have dealt with the form and style of the typical constituents of an assemblage; the objective has been to isolate specific industries and to follow their development and interaction through regularities and variations in the frequencies of these tool types. Yet ". . . a morphological typology does not tell us much about the activities of the human group which fabricated the implements;"[1] i.e. very few behavioral implications can be gleaned from a strictly morphological consideration of lithics. Functional and technological considerations, however, have been offered in lieu of morphological types in an effort to go beyond the mere shape of the object to the behavioral aspects of both manufacture and utilization.[2]

Experimentation with the manufacture and use of lithic artifacts may never provide definitive answers to questions such as how an object was made or used, but controlled experimentation and ethnoarchaeological studies[3] can delineate technological and functional patterns similar to those found in a prehistoric context, and from these regularities of damage and wear patterns can be discerned probable methods of manufacture, modes of utilization, and materials worked. Therefore, specific tool categories need to be experimentally manufactured and utilized under controlled and quantifiable conditions to test assumed functions of morphologically similar objects.

The manufacture and use of the morphologically-defined lithic artifacts called burins are subjects surrounded by controversy. It has been suggested: 1) that the burin is a core from which usable burin spalls can be detached, and that the major function of the burin is the production of other tools;[4] 2) that the removal of a

1. F. Bordes, "Reflections on Typology and Techniques in the Palaeolithic," *ArcAnth* 6:1 (1969) 1-29.

2. S. Semenov, *Prehistoric Technology* (Bath 1964); D. Crabtree, "A Stoneworker's Approach to Analyzing and Replicating the Lindenmeier Folsom," *Tebiwa* 9:1 (1966) 3-39. D. Crabtree, "Mesoamerican Polyhedral Cores and Prismatic Blades," *AmAnt* 33 (1968) 446-78; D. Crabtree, "Flaking Stone with Wooden Implements," *Science* 169:3941 (1970) 146-53; M. Newcomer, "Some Quantitative Experiments in Handaxe Manufacture," *WA* 3:1 (1972) 85-94; C. Keller, "The Development of Edge Damage Patterns on Stone Tools," *Man* 1:4 (1966) 501-11; G. Frison, "A Functional Analysis of Certain Chipped Stone Tools," *AmAnt* 33 (1968) 149-55; R. Gould, D. Koster and A. Sontz, "The Lithic Assemblages of the Western Desert Aborigines of Australia," *AmAnt* 36 (1971) 149-69; B. Hayden and J. Kamminga, "Gould, Koster and Sontz on 'Microwear': A Critical Review," *Newsletter of Lithic Technology* 2:1-2 (1973) 3-8; P. Sheets, "Edge Abrasion during Biface Manufacture," *AmAnt* 38 (1973) 215-8; E. Wilmsen, "Lithic Analysis and Cultural Inferences: A Paleo-Indian Case," *Anthropological Papers No. 16* (University of Arizona Press, Tucson 1970); R. Tringham et al., "Experimentation in the Formation of Edge Damage: A New Approach to Lithic Analysis," *JFA* 1 (1974) 171-196.

3. Gould, Koster and Sontz, op.cit. (in note 2).

4. J. Giddings, "The Burin Spall Artifact," *Arctic* 9:4 (1956) 229-37; D. Anderson, "A Stone Age Campsite at the Gateway to America," *SAm* 218 (1968) 24-33.

burin spall is a resharpening technique;[5] 3) that the burin spalls are removed through accidental impact blows and the burin is an amorphous, undefined tool type; and, 4) that the burin is a tool, assumed to have been utilized in the working of bone and antler. Classificatory schemes of burins have emphasized morphological characteristics,[6] although some cursory functional studies and considerations of burins have been published.[7] Gunn has applied a geometric model to the study of the utilization of burins, and his work has formed the basis of my research.[8]

Interpretive or functional emphasis on bone/antler-working is currently a wide-spread but unwarranted and untested assumption. Other possible uses of burins and other bone/antler working tools need to be considered (e.g. an unmodified flake with an appropriate edge angle could adequately be used to cut or incise bone, a burin could be used to scrape or engrave wood, or other material). In short, ". . . the working of bone being the unique purpose of the burins remains to be demonstrated, as well as the fact that the burins are the only means of working bone."[9]

In an effort to resolve some of the above problems, burins were manufactured experimentally and used on various materials in order to determine differences in wear due to manufacture and utilization.

Manufacture

Raw materials used in the manufacture of the burins included obsidian from Wagner Ranch, Ashfork, Arizona, and Mexico; fine-grained basalt from Wagner Ranch; and chert from Harrison County, Indiana, and Flint Hills, Kansas. Burin spalls were detached from flakes and blades with a hard-hammer, soft-hammer (elk antler), and by the pressure technique. Two "types" of burins were manufactured; unihedral and dihedral burins. Unihedral burins equate with de Sonneville-Bordes and Perrot's burins on a straight, oblique, concave, or convex truncation where the burin blow is struck on the truncated end of a blade or flake creating a burin edge at the junction (FIG. 1).[10] Dihedral burins equate with de Sonneville-Bordes and Perrot's straight or inclined dihedral burins, or dihedral on an angle, where two opposing burin blows meet to form the working edge (FIG. 1).

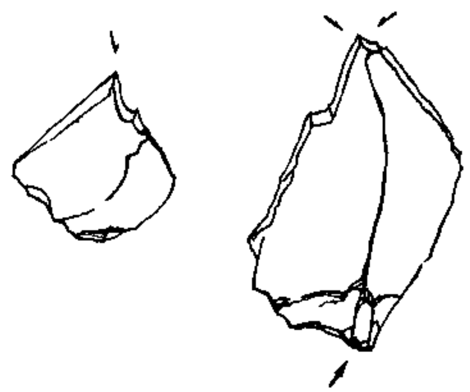

Figure 1. Examples of unihedral (left) and dihedral burins (right).

A total of 363 burins were manufactured, 181 unihedrals and 182 dihedrals. Twenty burins were manufactured for each raw material, manufacturing technique, and type of burin (e.g. 20 basalt hard-hammer dihedrals). The extra three burins constitute an obsidian hard-hammer unihedral, obsidian hard-hammer dihedral, and an obsidian pressure dihedral.

The burins were examined both macro- and microscopically after manufacture and the following characteristics were noted and recorded: 1) presence/absence of a negative bulb of force; 2) presence/absence of loss of material; 3) presence/absence of undulations; 4) presence/absence of striations; 5) number of hinge fractures; 6) number of invasive fractures; 7) condition of the edge; 8) presence/absence of eraillures; and 9) presence/absence of multiple scarring. In all but 12 cases, the burin spalls were recovered and loss of material was determined through the replacement of the spall on the burin. When this was impossible an estimate of material loss was made on the basis of the amount of fractures evident. A hinge or stepped

5. W. Mayer-Oakes, "Early Man in the Andes," *SAm* 208 (1963) 116-28.

6. H. Noone, "A Classification of Flint Burins or Gravers," *JRAI* 64 (1934) 81-92. H. Noone, "Burins of the Vezere Valley (Dordogne)," *Bulletin of the Prehistoric Society* 19:4 (1953) 116-20; M. Burkitt, *The Old Stone Age: A Study of Paleolithic Times* (New York 1956). A. Ronen, "The Typology of Paleolithic Stone Implements: Old World" (MS on file Arizona State University) translation of D. de Sonneville-Bordes and J. Perrot, "Lèxique Typologique du Palèolithique Superieur," *BSPF* 53 (1956) 408-12; J. Bordaz, *Tools of the Old and New Stone Age* (Garden City, NY 1970).

7. Semenov,, op. cit. (in note 2); J. Epstein, "Burins from Texas," *AmAnt* 26 (1960) 93-7; J. Epstein, "Towards the Systematic Description of Chipped Stones," *Proceedings of the 35th International Congress of Americanists* 35:1 (1962) 155-69; F. Bordes, "Utilisation possible des côtes des burins," *Fundberichte aus Schwaben, Neue Folge* 17 (1965) 3-4; F. Bordes, op. cit. (in note 1); J. Clark and M. Thompson, "The Groove and Splinter Technique of Working Antler in the Upper Paleolithic and Mesolithic Europe," *ProcPS* 19:6 (1953) 148-60.

8. J. Gunn, "A Geometric Model to Analyze the Place of Prehistoric Tools in an Economic System," (Paper read at the American Anthropological Association, Annual Meetings, San Diego 1970).

9. Bordes, op. cit. (in note 1) 19.

10. De Sonneville-Bordes and Perrot, op. cit. (in note 6).

Figure 2. Examples of invasive (left) and hinge fractures (right) (after Hayden and Kamminga, op. cit. in note 2).

Figure 3. Pointed edge resulting from the depression created by the positive bulb on the spall.

fracture is defined as one which terminates in a "more or less abrupt upswing of the fracture scar to the implement surface;" an invasive fracture as one which "widens to a shallow scar and becomes increasingly shallow with distance from the impact point" (FIG. 2).[11] No distinction was made between a hinge fracture where the termination is usually rounded or blunt, and a stepped fracture which "terminates abruptly in a right angle break at the point of truncation;"[12] both were included in the category hinge fracture. The condition of the burin edge was coded as fresh, crushed and pointed. Initially, the crushed category was divided into crushed, jagged, and nibbled, representing decreasing amounts of damage, but these were later collapsed into the single category of crushed. Likewise, the four burins originally classified with slight damage due to manufacture were included in the category fresh. Consequently, fresh is defined as exhibiting little or no damage along the edge; and crushed as exhibiting moderate to extensive damage. A pointed edge is one in which two points result on the edge from the positive bulb of the spall leaving an accompanying negative bulb on the burin (FIG. 3). Eraillures are flakes formed between the bulb of force and the negative bulb. Multiple scarring was noted when two or more burin spalls resulted from one blow.[13]

To obtain an index of working strength of the burin, the following measurements were taken: edge width; burin angle formed by the intersection of the burin face and the striking platform in the case of a unihedral, or by the intersection of the two burin faces in the case of a dihedral; and dorsal width and face width (FIG. 4). A 5 mm. perpendicular was dropped from the juncture of the burin scars or from the burin scar and the truncation, and width measurements were taken across the dorsal face and the face of the burin scar at this point. When two face widths were possible (i.e., in the case of a dihedral) both measurements were taken, but only the larger one was used in the analysis because it was

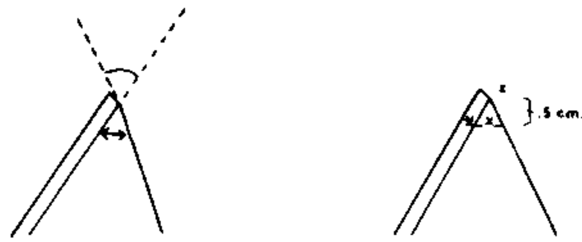

Figure 4. Burin angle; x, dorsal width; y, face width; and z, edge width as measured from a 0.5 cm. perpendicular.

assumed to contribute more to the working strength of the burin.

Utilization

In order to decrease the sample to a workable number, 216 of the 363 burins were randomly selected for utilization. Hard wood (hard maple), soft wood (pine), dry bone, and soaked bone (immersed in water for 24 hours) were worked in both a scraping and graving motion. As defined by Gunn,[14] in a scraping mode the edge of the burin is perpendicular to the direction of the movement, and in a graving mode the edge of the burin is parallel to the direction of the movement (FIG. 5). Prior to utilization, a thin wash of white or black India ink was applied to the burin to better distinguish manufacture damage from that caused by utilization. When a flake was detached, it removed the wash, and wear accumulated on the burin through utilization could thus be distinguished from previous damage.

All unihedral burins were utilized in a scraping mode and all dihedrals in a graving mode. Nine burins were worked for each raw material type, utilized material and mode of utilization (e.g. nine unihedral obsidian burins, three hard-hammer, three soft-hammer and three pressure, were used in a scraping motion on hard wood). All burins were worked for 100 strokes because the pressure applied to each stroke was easier to control when the strokes were counted than when utilization occurred for a specified period of time during which later strokes often became lighter because of fatigue.

After use, microscopic analysis was again undertaken

11. Hayden and Kamminga, op. cit. (in note 2) 7-8.

12. D. Crabtree, "An Introduction to Flintworking," *Occasional Papers of the Idaho State Museum, Number 28* (Pocatello 1973) 93.

13. A. Jelinek, B. Bradley and B. Huckell, "The Production of Secondary Flakes," *AmAnt* 36 (1968) 198-200.

14. Gunn, op. cit. (in note 8).

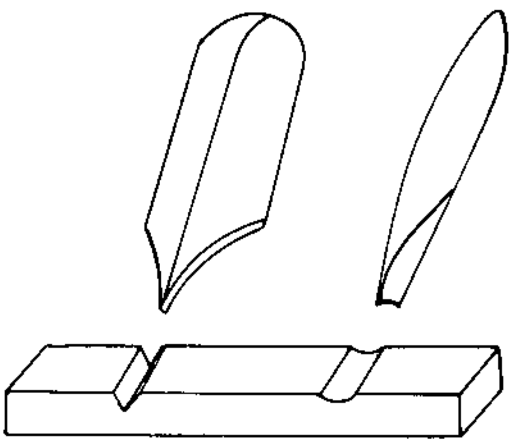

Figure 5. Two modes of burin utilization: graving (left) and scraping (right) (after Gunn, op. cit. in note 8).

and the following characteristics recorded: 1) number of hinge fractures; 2) number of invasive fractures; 3) number of burin scars; and 4) condition of the utilized edge. During use a minute burin spall could be removed from the impact of the burin upon the material worked, and the location of this scar and the number were recorded. The condition of the utilized edge was coded as: 1) crushed: exhibiting extensive damage; 2) nibbled: slight damage consisting of very tiny scars; 3) rounded: blunting or smoothing of angular surfaces; 4) fresh: little or no damage; 5) hinges present on the edge itself; and 6) invasives present on the edge.

Prior to and after utilization, the burins were washed to remove any foreign material and weighed on an electronic scale sensitive to a ten-thousandth of a gram to determine weight loss due to utilization.

Statistical Analysis

All of the variables considered in burin manufacture and utilization were analyzed with the Statistical Package for the Social Sciences (SPSS).

Independent variables considered in the manufacture process were the raw material of the burin (obsidian, basalt, chert) and the manufacturing technique (hard-hammer, soft-hammer, pressure). Chi-square tests were run on these independent variables and the dependent nominal variables (presence/absence of negative bulb, loss of material, undulations, striations, eraillures, multiple scarring, and condition of the edge) with the null hypothesis being no difference in damage according to the different independent variables. Significant differences between the nominal variables are summarized in Table 1.

Negative Bulb

Chi-square results for the presence/absence of a negative bulb were significant for the three types of raw material. No chert burins lacked a negative bulb, but 7 obsidian (5.7%) and 2 basalt (1.7%) ones did. Burins manufactured out of obsidian tend to show a higher incidence of straight-sided spalls and burin faces, rather than a negative bulb on the burin and a corresponding positive bulb on the spall as did chert burins.

Loss of Material

A significant difference for the presence/absence of loss of material for the three manufacturing techniques was found. In 30 of the 121 burins (24.8%) manufactured by the pressure method, no loss was evident, but only 3 of the 122 (2.5%) and 7 of 120 (5.8%) burins manufactured by the hard-hammer and soft-hammer methods, respectively, showed no loss of material upon replacement of the spall. To further isolate this difference, each raw material category was separated out and Chi-square tests run between loss of material and manufacturing technique. These tests established that manufacture technique was highly correlated with loss of material. Pressure burination yielded the greatest number of burins without any loss of material and hard-hammer burination the least.

Undulations

The presence/absence of undulations differed according to raw material with undulations being present most often on obsidian burins, and relatively scarce on chert burins; 69 obsidian burins (56.1%) showed undulations, but only 45 basalt burins (37.5%) and 27 chert burins (22.5%) showed them. For each manufacturing technique, Chi-square tests were run between presence/absence of undulations and raw materials. Obsidian again exhibited the largest number of undulations for each technique of manufacture (i.e., hard-hammer, soft-hammer, pressure), while basalt and chert fluctuated.

Striations

Striations were found to vary according to both raw material and manufacturing technique. With respect to raw material, chert showed the least number of striations, 16 (13.3%), while basalt and obsidian were similar, 38 (31.7%) and 42 (34.1%), respectively. In partitioning for the presence/absence of striations by raw material for each manufacturing technique, only the soft-hammer method of manufacture showed a significant Chi-square value and this being in the same patterns as above, with 7 (17.5%) chert burins, 16 (40%) basalt and 20 (50%) obsidian burins manufactured by a

Table 1. Summary table of nominal characteristics for the three raw materials and the three manufacturing techniques of the burins. OB — obsidian, BA — basalt, CH — chert, HH — hard-hammer, SH — soft-hammer, PR — pressure, H — high frequency, L — low frequency. Only significant characteristics as defined by the Chi-square tests are included.

	Negative Bulb	Loss of Material	Undulations	Striations	Condition of the edge	Eraillures	Multiple Scarring
OB	L		H		crushed	H	
BA							
CH	H		L	L		L	
HH		H			crushed		
SH					fresh		H
PR		L		L	pointed	H	L

soft-hammer showing striations.

The presence/absence of striations was also significant according to manufacturing technique, and for manufacturing technique with each raw material separated out. In all cases the pressure technique showed the lowest incidence of striations, and hard-hammer and soft-hammer frequencies were comparable. Twelve pressure-manufactured burins showed striations, while 41 hard-hammer and 43 soft-hammer manufactured ones did. Thus, striations seem to occur more often in manufacture when a sharp blow is applied (e.g., with a hard or soft hammer) than when a pressure technique is used.

Condition of the Edge

As stated, the variables originally defined for condition of the edge were eventually grouped as crushed, fresh, and pointed; differences were significant for both raw material and manufacturing technique. Obsidian burins showed the highest incidence of crushed edges (56), and the lowest occurrence of pointed ones (25). Basalt and chert were characterized by similar edge conditions: basalt showed 29 crushed, 40 fresh and 51 pointed edges; and chert, 22 crushed, 41 fresh and 57 pointed edged. In regard to manufacturing technique, the number of crushed edges decreased from hard-hammer to pressure techniques. Fifty-one (41.8%) hard-hammer manufactured burins had crushed edges, whereas only 38 (31.7%) soft-hammer and 18 (14.9%) pressure burins had crushed edges. Soft-hammer manufactured burins showed a high incidence of fresh edges; and pressure-manufactured burins showed a high incidence of pointed edges.

Eraillures

The presence/absence of eraillures also was significant by raw material and by manufacturing technique. Chert showed the lowest incidence of eraillures, 8 (6.7%), and obsidian the highest, 22 (17.9%), with basalt being intermediate, 14 (11.7%). With respect to manufacture technique, the pressure method resulted in the presence of 24 (19.8%) eraillures, while the hard and soft-hammer methods each resulted in 10 (8.2% and 8.3%). When broken down by raw material, the three subsequent Chi-square results between the presence of eraillures and manufacture technique for each raw material showed that only chert had a significant difference with 6 pressure eraillures, and one eraillure each for hard and soft-hammer methods.

Multiple Scarring

Multiple scarring was most frequent, 14 (11.7%), on soft-hammer manufactured burins, and least common on pressure-manufactured burins, 2 (1.7%), while hard-hammer burins showed 9 (7.4%) incidences of multiple scarring. The only other significant result obtained was for obsidian burins according to manufacture with 6 (15%) soft-hammer, 2 (4.8%) hard-hammer and no pressure occurrences.

Jelinek, Bradley and Huckell state that the only two factors associated consistently with the production of multiple flakes were: "(1) the presence of a ridge of some sort on the face of the core which the flakes followed as they were struck, and (2) a broad area of contact between the hammerstone and the core."[15]

15. Jelinek, Bradley and Huckell, op. cit. (in note 13) 200.

Table 2. Mean numbers of hinge and invasive fractures resulting from manufacture.

Type of Burin	Hinge Mean	Invasive Mean	Number
All	2.388	1.226	363
Obsidian	2.715	1.398	123
Basalt	2.083	1.392	120
Chert	2.358	.882	120
Hard-hammer manufacture	3.000	1.549	122
Soft-hammer manufacture	2.633	1.333	120
Pressure manufacture	1.529	.793	121
Obsidian, hard	2.929	1.548	42
Obsidian, soft	3.325	1.575	40
Obsidian, pressure	1.902	1.073	41
Basalt, hard	3.100	1.850	40
Basalt, soft	1.975	1.575	40
Basalt, pressure	1.175	.750	40
Chert, hard	2.975	1.250	40
Chert, soft	2.600	.850	40
Chert, pressure	1.500	.550	40

They further suggest that the use of a blunt hammerstone is implied in regard to this last observation. This coincides with the higher incidence of multiple scarring on soft-hammer manufactured burins and the lower incidence on pressure manufactured ones. The elk antler employed as a soft hammer was broader and produced a greater area of contact with the flake to be burinated than did either the hard hammer or the pressure tool.

Hinge and Invasive Fractures

Chi-square tests were run on the presence/absence of invasive and hinge fractures due to manufacture, with equal weight being given to both categories if a single burin showed both types of fractures. The largest Chi-square value obtained (1.56) did not approach any significance level.

Two-sample tests of means (significance of difference tests) were used to determine whether the differences of the means of the kinds of fractures represented were due to chance variation, or were representative of probable real differences (TABLE 2).[16] In all cases except two (basalt burins manufactured with a soft hammer and the pressure technique) there was a significant difference between the two kinds of fractures with hinge fractures being more prevalent.

One-way analysis of variance (an extension of the two-sample test of means used to delineate relationships between a nominal, or higher order scale, and an interval scale) was used to isolate differences within hinge and invasive fractures by raw material and manufacture technique.[17] Both the number of hinges and the number of invasives differ significantly for manufacture technique with decreasing amounts of wear from the hard-hammer, soft-hammer, and pressure techniques. However, in regard to raw material, only the invasive fractures were significant with obsidian and basalt having almost identical mean invasive fractures of 1.398 and 1.392, respectively, and chert having a mean of .883.

All three raw materials showed significant differences in their mean number of hinge fractures when sorted by the three methods of manufacture. Basalt and chert follow the pattern stated above for all burins with hard-hammer manufactured burins showing the most damage in the number of hinges present and pressure the least. When obsidian burins are considered, however, soft-hammer manufactured burins show a higher incidence of hinge fractures than do hard-hammer ones. Basalt and chert also show a difference for invasive fractures with hard-hammer manufactured burins showing the most damage and pressure the least. When the three manufacturing techniques are separated, only the soft-hammer method contains significant differences for the mean number of hinges and invasives. For hinges, obsidian soft-hammer burins have the largest mean, then, chert and basalt (3.325, 2.600 and 1.975, respectively), but for invasives, obsidian and basalt have identical high means (1.575), with chert having a mean number of .850 invasive fractures. Thus, more extensive hinge fracture damage, but not invasive fracture damage, results on obsidian burins manufactured by the soft-hammer method than by the other two manufacture methods. Both basalt and chert show differences for hinge and invasive fractures in decreasing amounts of damage for hard-hammer, soft-hammer, and pressure methods, while soft-hammer manufactured burins show differences for both fractures but in a different order (i.e., soft-hammer obsidian burins show the most hinge fracture damage and basalt the least, while obsidian and basalt show the most invasive fracture damage and chert the least).

Utilization

Independent variables considered in the utilization of the burins were the raw material of the burin, the mode of utilization, edge width, burin angle, dorsal width, face width, and utilized material.

Two-sample tests of means were conducted on the mean measurements of the burins in order to reduce the number of independent variables that needed to be considered. No significant differences were found between the raw materials when tested for edge width. Mean

16. H. Blalock, *Social Statistics* (New York 1972) 220-228.

17. Ibid., 317-328.

edge widths for obsidian, basalt, and chert were 3.7 mm., 3.8 mm., and 3.3 mm., respectively. According to the associated probability, the mean burin angle is significantly different between obsidian (73.1°) and basalt (74.3°) and between obsidian and chert (75.2°), but upon inspection of the angles involved, the differences were considered to be too slight (i.e., one or two degrees) to be of any major importance. These differences probably reflect more measurement error than a causative factor in consequent wear patterns. However, significant differences do occur between the raw materials for both dorsal width and face width. In regard to face width, chert is responsible for all variation with a mean face width of 4.3 mm., and no significant differences were found between obsidian and basalt. Obsidian and basalt showed mean face widths of 5.1 mm. and 4.8 mm., respectively. With respect to dorsal width, all three raw materials showed variations between themselves and the other two: mean dorsal widths for obsidian, basalt, and chert were 8.2 mm., 7.7 mm. and 6.8 mm., respectively. Even though dorsal width and face width show differences statistically, the actual measured difference is very slight (1-2 mm.). As a result of the two-sample tests of means, edge width and burin angle no longer need to be considered as independent variables, but dorsal width and face width cannot be so easily eliminated. However, because of the slight variation evident in dorsal and face width measurements, they may still be unimportant factors in the resultant wear patterns.

Two-sample tests of means were also run on: 1) the mean number of hinge fractures accumulated through use in a scraping or a graving mode; 2) the mean number of invasives between scraping and graving modes; 3) the mean number of burin scars for scraping and graving; and 4) the mean number of hinges and invasives for all burins, the three raw materials, the four utilized materials, and the two modes of use (TABLE 3).

The results of these tests showed that more hinge fractures and burin scars are accumulated on the burin face through the scraping mode of use, and that more invasive fractures accumulate in a graving mode of use. Two-sample tests of means between hinge and invasive fractures for all burins, the three raw materials, the materials worked, and the two modes of use all produced significant results with hinge fractures always being more prevalent than invasive fractures except in the case of soft wood. When the burins were utilized on soft wood, more invasive fractures resulted than did hinge fractures (1.722 and .889, respectively). Tests were not run on the differences between the number of hinges and the number of invasives for the different raw materials utilized in different modes on different materials because of the small number involved in each case (e.g., nine obsidian burins worked in a graving mode on hard wood). Inspection of the means of the fractures for each category (TABLE 3), however, reveals that all follow the pattern of more hinges resultant from utilization of hard wood, soaked bone, or dry bone except for basalt burins utilized to grave bone. All burins worked on soft wood show a greater number of invasive fractures except obsidian and basalt burins scraped on soft wood.

Table 3. Mean number of hinge and invasive fractures and burin scars accumulated through utilization.

Dependent Variable	Hinge	Invasive	Burin Scars
All	3.083	1.519	.144
Obsidian	3.375	1.542	.194
Basalt	3.389	1.944	.125
Chert	2.486	1.069	.111
Scraping mode	3.620	1.204	.231
Graving mode	2.546	1.833	.056
Hard wood	3.111	1.722	.111
Soft wood	.889	1.722	.111
Soaked bone	3.204	1.463	.111
Dry Bone	5.130	1.167	.241
Ob graving hard wood	3.222	2.111	.000
Ob graving soft wood	.778	1.778	.000
Ob graving soaked bone	2.000	1.222	.111
Ob graving dry bone	5.444	1.667	.333
Ba graving hard wood	3.222	2.333	.111
Ba graving soft wood	.333	2.667	.000
Ba graving soaked bone	4.111	4.222	.111
Ba graving dry bone	4.222	1.889	.000
Ch graving hard wood	1.889	.667	.000
Ch graving soft wood	.333	1.556	.000
Ch graving soaked bone	.778	.667	.000
Ch graving dry bone	4.222	1.222	.000
Ob scraping hard wood	3.222	2.111	.333
Ob scraping soft wood	1.778	1.222	.333
Ob scraping soaked bone	4.333	1.667	.111
Ob scraping dry bone	6.222	.556	.333
Ba scraping hard wood	4.000	1.889	.111
Ba scraping soft wood	1.222	1.222	.333
Ba scraping soaked bone	4.000	.556	.222
Ba scraping dry bone	6.000	.778	.111
Ch scraping hard wood	3.111	1.222	.111
Ch Scraping soft wood	.889	1.889	.000
Ch scraping soaked bone	4.000	.444	.111
Ch scraping dry bone	4.667	.889	.667

One-way analysis of variance was used to determine differences within the number of hinges for different groups, and within the number of invasives. Significant F values showed that the number of invasive fractures varied according to raw material, and that the number of hinge fractures varied according to the material utilized. The number of invasive fractures was significantly different for the following groups: 1) raw materials, 2) raw material for burins worked on soaked bone, and 3) raw material for burins worked in a graving motion. In contrast, the number of hinge fractures was significant in the one-way analysis of variance for the following: 1) utilized material, 2) utilized material for obsidian burins, 3) utilized material for basalt burins, 4) utilized material for chert burins, 5) utilized material for burins worked in a graving motion, and 6) utilized material for burins worked in a scraping motion.

Invasive fractures in all cases with significant F's varied according to the three groups of raw material with basalt showing the greatest number of invasives and chert the fewest. Variations among the number of hinge fractures for the four materials worked always show the greatest number of hinges when dry bone was utilized, and the least when soft wood was utilized. Mean number of hinges for hard wood and soaked bone fluctuated.

Condition of the Utilized Edge

Chi-square tests were used to distinguish significant differences among utilized edge according to the various raw materials of the burins, the materials worked, and the mode of utilization.

No differences were evident in the utilized edge condition according to raw material of the burin (Chi-square = 12.73, p[robability] = .39, i.e., the likelihood of this condition occurring by chance alone is 39 out of 100 or 39%), but significant differences were evident for edge condition according to material utilized (Chi-square = 70.9, p = .0) and mode of utilization (Chi-square = 27.9, p = .001) such that the following conclusions can be made. 1) Burins worked on dry bone show a high occurrence of crushed and nibbled edges, and a low occurrence of fresh edges. 2) Burins worked on soft wood show a low occurrence of crushed edges and a high occurrence of fresh ones. 3) Burins used in a scraping mode show a high incidence of crushed and nibbled edges. 4) Burins used in a graving mode show a high incidence of hinge fractures present on the burin edge.

Burin Scars

There were not enough instances of burin scars accumulated on the face of the burin through utilization to run either analysis of variance or two-sample tests of means. A one-sample Chi-square test[18] was run on the total number of burin scars resulting from the scraping and graving modes of use, but the Chi-square value of 2.28 was not significant. No other attempted Chi-square, except utilized material for scraping mode and raw material for graving mode, could satisfy an expected frequency of at least five; in fact, most expected frequencies ranged from .5 to 2.8. In the two contingency tables in which expected frequencies were five or greater (type of material worked in a scraping motion and type of material worked in a graving motion), the Chi-square values were insignificant.

Weight Loss

Weight loss due to utilization was determined by the difference in weights before and after utilization. Descriptive statistics were calculated for weight loss according to the various burin categories. Inspection of the means revealed no apparent pattern as was predicted on the basis of previously run tests (e.g., burins worked on soft wood should show the least amount of weight loss, while those worked on dry bone the most).

Chert burins show an inordinately large amount of weight loss when compared to obsidian and basalt burins (0.0083 g. as compared to 0.0024 and 0.0021, respectively). This may reflect the greater strength and durability of chert as a raw material enabling chert burins to accumulate more wear, or the relative weakness or softness of chert when compared to basalt and obsidian. It may also reflect error in measurement. It is recognized that weight loss can never be determined on burins found in a prehistoric context. Therefore, weight loss due to utilization was not considered further as a dependent variable in burin utilization. However, the recording of before and after utilization weights of lithic objects may prove to be of value in future experimental studies.

Discriminant Analyses

Discriminant analyses were conducted to distinguish statistically between the three techniques of burin manufacture and between the four groups of materials worked. Discriminating variables are selected which measure characteristics on which the groups are expected to differ. These variables are then weighted and combined linearly such that the groups formed are as statistically distinct as possible.[19] To hold constant the

18. S. Siegel, *Nonparametric Statistics for the Behavioral Sciences* (New York 1956) 42-47.

19. W. Cooley and P. Lohnes, *Multivariate Data Analysis* (New York 1971) 243-255.

effect of raw material, each raw material type was run separately (i.e., six runs were made on obsidian manufacture, obsidian utilization, etc.). A step-wise discriminant program (Biomedical Computer Program O7M) was used in order to allow free entry of all variables.

Manufacture

Burins were scored on the nine variables described earlier under the main heading "Manufacture." These variables were considered important for discrimination among hard-hammer, soft-hammer, and pressure manufacturing techniques and used in the following analyses.

Obsidian

A step-wise discriminant analysis was performed on all obsidian burins using the nine variables. However, the first run produced a classification in which loss of material was the most important discriminator. Since this variable usually is not recoverable from archaeological data, it was deleted from the analysis. The following discussion will deal with the classification of obsidian burins on the remaining eight variables.

A significant value for the F statistic (significant at .05) resulted for overall group separation of the three manufacturing methods for obsidian burins; pressure manufacture can be separated from both hard and soft-hammer methods of manufacture. No less than 75% (30 of 41) of the burins manufactured by the pressure technique were classified correctly (i.e., of the 41 obsidian burins manufactured by pressure, 30 were placed into the correct experimental group of pressure manufacture). Only 50% (21 of 42) and 55% (22 of 40) of the hard-hammer and soft-hammer manufactured burins (respectively) were classified correctly.

To determine which variables were critical in the analysis, the final F statistics for each variable were examined. The individual F values for each variable change as additional variables are entered into the equation. Only variables 4, 9 and 6 (presence/absence of striations, presence/absence of multiple scarring and number of hinge fractures) had F values high enough to be significant at the .05 level (i.e., these variables account for most of the separation obtained in the classification).

Basalt

Basalt burins grouped by manufacturing method were separated by disciminant analysis. Individual group separation was significant for all methods of manufacture. The percentage of correct varied from 60% (soft-hammer) to 72.5% (pressure). Hard-hammer manufactured burins showed 65% correct classification.

Variables with significant F values for separation of the three techniques of manufacture included number of hinge fractures, number of invasive fractures, and condition of the edge.

Chert

As with obsidian and basalt burins, the overall group separation of chert burins by method of manufacture was statistically significant. Individual separation of the methods segregated pressure from the other two techniques.

Percentages of correct classifications varied from 42.5% to 76.5%. Twenty hard-hammer manufactured burins (50%) were classified correctly, whereas 17 soft-hammer manufactured burins (42.5%) and 27 burins manufactured by the pressure technique (67.5%) were classified as to their correct category.

Utilization

Discriminant analysis was also used to separate the four materials worked: 1) soft wood, 2) hard wood, 3) soaked bone, and 4) dry bone. The variables used initially in the analysis included: 1) number of hinge fractures; 2) number of invasive fractures; 3) number of burin scars accumulated through use; 4) total number of fractures (hinges + invasives + burin scars); 5) condition of the utilized edge scored as fresh — 1, rounded — 2, hinges present, invasives or burin scars present — 3, nibbled — 4, and crushed — 5; 6) edge width; 7) edge angle; 8) dorsal width; and 9) face width. Since variable 4 is redundant and is a function of the first three, it was excluded. Variables 6-9 were also excluded because, upon inspection of the classification of materials worked, they were never significant in the final classification of the four materials worked. Variable 9 was picked second in the separation of the materials for obsidian burins, but when all other variables were considered, it was no longer significant at the .05 level. Each raw material type was considered in turn in order to hold the effect of raw material constant.

Obsidian

Overall group separation of obsidian burins according to material worked was significant at the .05 level. Dry bone was separated from all the others, but no other materials worked were.

Percentages of correct classification varied from 16.7% to 72.2%. Soft wood and dry bone had the lowest incidence of misclassification. Out of a possibility of 18, 13 burins worked on soft wood and 12 burins worked on dry bone were classified correctly. Only 7 worked on hard wood and 3 worked on soaked bone were placed in their correct category. Thus, the hardest and softest materials worked were separated, while the intermediate ones were not.

Upon inspection of the order in which the variables were entered into the equation, hinge fractures were significant in the overall group classification (F value 7.22).

Basalt

Overall group separation for basalt burins as to material worked was also significant. Burins used on soft wood were separated from burins used on all other raw materials. Thus, only soft wood utilized burins produced a high percentage of correct classification (83.3%). As with obsidian burins, the number of hinge fractures was the only variable with a significant F value (4.37).

Chert

As with the other raw materials, overall group separation of chert burins was statistically significant. Discrimination by material worked showed soft wood and dry bone to be separated from hard wood and soaked bone; i.e., the softest and the hardest materials were discriminated in the analysis, but the intermediate ones were not.

Accordingly, soft wood and dry bone show the highest percentages of correct classification (61% each). However, discrimination was not exceptional in any case, with probabilities of misclassification ranging from 39% to 66%. Again, the number of hinge fractures was the only significant variable in the separation (F = 3.63).

Obsidian pressure manufactured burins were discriminated from those of hard-hammer and soft-hammer manufacture by the presence/absence of striations, presence/absence of multiple scarring and the number of hinge fractures. Burins manufactured by the pressure technique showed a low incidence of all three of these variables.

All methods of manufacture were separated for burins made of basalt by the number of hinge fractures, the number of invasive fractures, and the condition of the edge. Hard-hammer, soft-hammer, and pressure manufactured burins exhibited decreasing amounts of hinge and invasive fractures, respectively. While basalt burins manufactured with a hard hammer showed a high incidence of crushed edges, soft hammer manufactured burins showed a high occurrence of fresh edges and pressure manufactured burins showed a high number of pointed edges.

As with obsidian, chert burins manufactured with a pressure technique were discriminated from the other two methods of manufacture. However, chert pressure manufactured burins were classified as to the number of invasive and the number of hinge fractures present on the burins. Each of these two variables showed decreasing amounts of damage from hard-hammer to soft-hammer to pressure manufacture.

The discriminating power of the number of hinge and invasive fractures supports the previously stated results of the analysis of variance. The means of both hinge and invasive fractures vary significantly according to the method of manufacture for basalt and chert burins, while only the number of hinge fractures varies according to manufacturing method for obsidian burins.

Comments

In general, pressure manufacture was separated from the other two methods for all burins. In addition, basalt burins were classified correctly according to all three types of methods of manufacture. In regard to utilization, only the hardest (dry bone) and the softest (soft wood) materials were discriminated. The two intermediate materials (hard wood and soaked bone) were never separated for any of the three types of raw material of the burins.

Obsidian, basalt and chert burins were discriminated according to the number of hinge fractures, even though the materials worked varied in the discrimination. Obsidian burins produced a separation of dry bone utilization; basalt burins produced a separation of only soft wood utilization; while chert burins produced a separation of both soft wood and dry bone utilization. The calculated means for the number of hinge fractures was high for dry bone utilization and low for soft wood utilization: 1) obsidian dry bone hinge fracture mean of 5.8, 2) basalt soft wood hinge fracture mean of .78, and 3) chert soft wood and dry bone hinge fracture means of .61 and 4.4. Thus the results of the discriminant analysis of materials worked supports the conclusion previously stated that on the basis of the one-way analysis of variance, the number of hinge fractures varies according to the material worked. The number of invasive fractures varied according to raw material of the burin, but this was held constant in the discriminant analysis.

Conclusion

Manufacture

A summary of all nominal variables for manufacture can be found in Table 1. The following conclusions can be extracted from the analysis of this table.

1) The presence/absence of a negative bulb varies according to raw material; no chert burin lacks a negative bulb, but a number of obsidian ones do.

2) Loss of material varies with manufacturing technique, with increasing amounts of loss from the pressure method, to the soft-hammer and hard-hammer methods of manufacture.

3) Obsidian burins show a high incidence of undulations while chert burins show a low incidence.

4) Striations vary as to both raw material and manufacture technique, being least prevalent on chert burins and on burins manufactured by the pressure method, while obsidian and basalt burins show equivalent frequencies of striations, as do hard- and soft-hammer manufactured burins.

5) Condition of the edge also varies with both raw material and manufacture method, crushed edges show their highest incidence on obsidian burins, and on burins manufactured by a hard-hammer, and their lowest incidence on pressure manufactured burins. Pointed edges occur most often when the pressure method of manufacture is used, and least often on obsidian burins; fresh edges occur most often on soft-hammer manufactured burins.

6) Eraillures occur most frequently on obsidian and pressure manufactured burins, and least often on chert burins.

7) Multiple scarring is highly correlated with the soft-hammer method of manufacture.

When hinge and invasive fractures are considered, more hinges than invasives result in all cases except for basalt soft-hammer manufactured burins and basalt pressure manufactured ones. Decreasing frequencies of both hinge and invasive fractures occur from hard-hammer, soft-hammer, and pressure manufacture, except for obsidian soft-hammer manufactured burins where more hinges result than obsidian hard-hammer manufactured burins. When the soft-hammer method of manufacture is compared to the other two, more hinges occur on obsidian burins, and fewer on basalt, while invasive fractures result most frequently on obsidian and basalt burins and least frequently on chert burins.

Therefore, the following characteristics of manufacture can be stated for the three raw materials and the three modes of manufacture.

1) Obsidian: general lack of negative bulbs of force and high occurrences of undulations, crushed edges and eraillures.

2) Basalt: no definite patterns discernible.

3) Chert: low incidence of undulations, striations, and eraillures; high incidence of negative bulbs.

4) Hard-hammer: crushed edges and high loss of material.

5) Soft-hammer: fresh edges and high frequently of multiple scarring.

6) Pressure: slight loss of material, striations, and multiple scarring; high incidences of eraillures and pointed edges.

Utilization

More hinge than invasive fractures result in the utilization of burins in different modes of use on different materials except when soft wood is worked, in which case more invasives result. Invasive fractures vary as to raw material and mode of use with high frequencies on basalt burins and on burins worked in a graving mode, while hinge fractures vary as to material utilized and mode of use with high frequencies resulting when dry bone is worked or when the burins are used in a scraping mode, and low frequencies resulting when soaked bone is worked or when the burins are used in a graving mode.

The following may be stated regarding the condition of the utilized edge.

1) Crushed edges occur most frequently when dry bone is worked and when a scraping mode is used, and least often when soft wood is worked.

2) Nibbled edges show their highest incidence when dry bone is worked or when a scraping mode is used.

3) Fresh edges rarely occur when dry bone is worked, but frequently occur when soft wood is worked.

4) Hinge fractures on the edge occur most often in a graving mode of use.

The following utilization characteristics can now be listed.

1) Graving mode: high occurrence of hinge fractures on the burin edge and a hinge: invasive ratio of 1.4:1.

2) Scraping mode: crushed, nibbled edges and a 3:1 ratio of hinge: invasive fractures.

3) Hard wood: a 1.8:1 ratio.

4) Soft wood: fresh edges and 0.5:1 ratio.

5) Soaked bone: a 2.2:1 ratio.

6) Dry bone: crushed, nibbled edges and a 4.4:1 ratio of hinge: invasive fractures (see TABLE 4 for other hinge: invasive fracture ratios).

To check the classification of the burins, discriminate analyses were made on all burins to separate them according to mode of manufacture and material worked on the basis of the damage characteristics outlined above. The three manufacturing techniques could be distinguished for all three raw material categories, but with varying degrees of precision. Pressure manufacture was distinguished in all cases, but only for basalt were all three techniques clearly separated. In regard to

Table 4. Hinge: invasive ratios for burin utilization.

Dependent Variable	Hinge: Invasive Ratio
Obsidian	2.2:1
Basalt	1.7:1
Chert	2.3:1
Scraping mode	3.0:1
Graving mode	1.4:1
Hard wood	1.8:1
Soft wood	.5:1
Soaked bone	2.2:1
Dry bone	4.4:1
Ob graving hard wood	1.5:1
Ob graving soft wood	.4:1
Ob graving soaked bone	1.6:1
Ob graving dry bone	3.3:1
Ba graving hard wood	1.4:1
Ba graving soft wood	.1:1
Ba graving soaked bone	1.0:1
Ba graving dry bone	2.2:1
Ch graving hard wood	2.8:1
Ch graving soft wood	.2:1
Ch graving soaked bone	1.2:1
Ch graving dry bone	3.5:1
Ob scraping hard wood	1.5:1
Ob scraping soft wood	1.5:1
Ob scraping soaked bone	2.6:1
Ob scraping dry bone	11.2:1
Ba scraping hard wood	2.1:1
Ba scraping soft wood	1.0:1
Ba scraping soaked bone	7.2:1
Ba scraping dry bone	7.7:1
Ch scraping hard wood	2.6:1
Ch scraping soft wood	.5:1
Ch scraping soaked bone	9.0:1
Ch scraping dry bone	5.2:1

utilization, the hardest and the softest materials worked were discriminated, but materials of intermediate hardness were not.

Differences in dorsal width and face width for chert burins were not considered in the univariate statistics. Inspection of the results of these tests shows that chert does not exhibit any extreme values except in the case of weight loss. The discriminate analyses of utilization of the burins did not show any extreme variation in regard to these two variables. Therefore, it is concluded that even though differences do occur in the means of the two widths for the three raw materials, the differences are too slight to be of any major consequence in the resultant wear patterns.

In conclusion, this experimental study delineated and evaluated the damage characteristics which resulted from different methods of manufacture and utilization of the burins. Employing the statistical regularities presented above, relatively large samples of prehistoric burins may be classified as to manufacture method and material worked. The distinction of damage characteristics is especially promising in regard to the relative hardness of the material worked (i.e., soft wood vs. dry bone). The results of these controlled experiments with burins suggest that similar studies of other lithic artifacts would provide valuable insights into the technological and functional patterns of past cultural systems.[20]

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