TOOLS UNDERFOOT: HUMAN TRAMPLING AS AN AGENT OF LITHIC ARTIFACT EDGE MODIFICATION

Sally McBrearty, Laura Bishop, Thomas Plummer, Robert Dewar, and Nicholas Conard

A series of eight replication experiments tests the proposition that human trampling of stone flakes can produce edge damage that mimics deliberate retouch. Retouchlike edge damage, breakage, and other forms of macroscopic mechanical damage were observed on large numbers of pieces in all trampled sets. Experiments measured the relative contributions of three variables—raw material, artifact density, and substrate—in generating damage. Results indicate that while all three factors contribute to some degree, substrate plays the most decisive role, and that artifacts are more likely to exhibit damage if trampled on an impenetrable substrate. It was further found that trampling transforms flakes into pseudo-tools that can be classified as formal tools using a standard typology. Many of these are notched and denticulate pieces, indicating that special caution is needed in behavioral interpretations based on these tool types, and that the European Paleolithic Denticulate Mousterian industry requires critical reassessment.

Una serie de ocho experimentos de réplica prueban la proposición de que el pisoteo humano de lascas líticas puede producir daños que imitan retoque deliberado. Este tipo de daños, rotura, y otras formas de modificación mecánica fueron observados en un gran número de piezas en los conjuntos pisoteados. Los experimentos midieron la contribución relativa de tres variables: materia prima, densidad, y sustrato, en la generación de daño. Los resultados indican que las tres variables contribuyen parcialmente, pero que el sustrato juega el rol más decisivo, y que los artefactos pisoteados sobre un sustrato impenetrable son los más dañados. También se encontró que el pisoteo transforma lascas en sustrato-herramientas que pueden ser clasificadas en categorías formales usando una tipología estándar. Muchas de éstas tienen muescas y denticulados, indicando que se necesita cautela en interpretaciones conductuales basadas en estos tipos de herramienta, y que la industria paleolítica del denticulado maeestriense necesita ser revisada críticamente.

The life history of a stone artifact can be divided into stages. It begins with raw material procurement, proceeds through manufacture, use, alteration, curation, and discard, continues through burial and diagenesis, and concludes with retrieval and study by the archaeologist. Not all artifacts experience this ideal history, but processes that operate at each stage may impart physical traces discernible on the artifact itself. Traditional artifact typologies concentrate on artifact manufacture, and definitions of archaeological industries have centered on stylistic information encoded in artifact form (e.g., Bordes 1961b; de Sonneville-Bordes and Perrot 1953, 1954, 1955, 1956a, 1956b; Kleindienst 1962; Leakey 1971; Tixier 1963).

For flake-based lithic industries, it is usually assumed that ultimate tool form is caused by the raw material selected, the techniques used in flake production, and the nature of the retouch. The introduction of actualism in the debate, with replication of core reduction sequences and reproduction of specific artifact types (e.g., Dibble 1984, 1985, 1987a, 1987b, 1987c, 1988a, 1988b, 1991; Jones 1981; Newcomer 1971; Rolland 1977, 1981, 1988; Rolland and Dibble 1990; Toth 1985; van Peer 1992), has led to a refinement in our appreciation of the roles of raw material selection and specific manufacturing techniques in determining tool form at the point of discard. Artifacts may also undergo unintentional macroscopic edge damage during manufacture (Newcomer 1976). The effects of deliberate use on artifact edges have been the subject of a large body of research, which has focused primarily on microscopic traces of use wear (see Yerkes and Kardulias 1993 and Grace

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1996 for recent reviews), although the importance of macroscopic use-wear traces has been pointed out by some researchers (e.g., Barton and Bergman 1982). The recognition of cutmarks on bone produced by stone tools (Bunn 1981; Potts and Shipman 1981) has complemented the growing body of data on artifact use wear.

The processes acting on artifacts after discard belong to the realm of taphonomy. Much taphonomical research has focused on factors affecting archaeological materials, primarily bone, either before burial, when the actions of carnivores and humans play the most significant roles, or during burial, when geologic agents, particularly fluvial processes, may dominate (e.g., Behrensmeyer 1982; Binford 1981; Brain 1981; Bunn 1986; Gifford-Gonzalez 1978; Gifford-Gonzalez and Behrensmeyer 1977; Hill 1984; Potts 1988; Schick 1986). Postdepositional processes also affect artifact preservation and distribution. Solifluction, cryoturbation, and colluvial action have long been recognized at both European and North American Pleistocene sites as potential culprits in compromising artifactual and stratigraphic integrity (Bordes and Bourgon 1951; Freeman 1978; Laville 1969), and there is a growing awareness of the importance of groundwater, differential compaction, plant growth, soil fauna, and human activities in altering site structure and artifact condition (Betts 1978; Bocek 1986; Cahen and Moeyersons 1977; Courtin and Villa 1982; Crossley 1986; Erdalsson 1984; Gifford-Gonzalez 1981; Hare 1980; Johnson 1989; McBrearty 1990; Moeyersons 1978; Rolfson 1980; Rowlett and Robbins 1982; Schiffer 1983, 1987; Stein 1983; Villa 1982; Villa and Courtin 1983; White and Hannus 1983; Wood and Johnson 1979). In caves, continuing dissolution of bedrock and the resulting collapse of sediments provide additional agents of disturbance (Glover 1979; Jelinek et al. 1973).

**Trampling as an Agent of Artifact Damage**

This paper reports the investigation of the effects of human trampling on stone artifacts. Stone tools and debitage, though often quite sharp, were no doubt routinely walked upon by prehistoric peoples. Deliberate removal of lithic debris from living areas has been observed for some modern flint knappers (Gallagher 1977), but such tidiness is by no means characteristic of all societies. In fact, Farizy (1990) notes that the habits of clearing and disposal of trash, including lithic waste, consistently distinguishes French Upper Paleolithic sites from those of the Middle Paleolithic, whose occupants appear to have allowed such material to accumulate in place. At some North American sites, activity areas have been defined on the basis of evidence of repeated trampling (Whittlesey et al. 1982). As has been noted by Pryor (1988), the reality of postulated Paleolithic site features, such as doors and passageways (e.g., de Lumley 1969), could be tested if the damaging effects of trampling were systematically codified.

Most previous work on human trampling has focused on the issue of how the process affects displacement of artifacts, particularly in the vertical dimension (Gifford-Gonzalez 1978; Gifford-Gonzalez and Behrensmeyer 1977; Gifford-Gonzalez et al. 1985; Hughes and Lampert 1977; Nielsen 1991; Siiriäinen 1977; Stockton 1973; Villa 1982; Villa and Courtin 1983; Wilk and Schiffer 1979; Yellen 1977). Trampling experiments by Shea and Klenck (1993) have shown that human trampling may obliterate prior traces of use wear or may inflict damage that resembles use wear. Other investigators have examined the role of trampling by animals in producing effects that mimic deliberate cutmarks and polish on bone (Behrensmeyer et al. 1986; Fiorillo 1984; Oliver 1989; Olsen and Shipman 1988) or the effects of trampling by humans, animals, and machinery on vegetation and soil compaction (Liddle 1975; Weaver and Dale 1978).

Archaeologists are aware that lithic artifacts, when encountered in survey on paths or in other heavily trafficked zones, are often broken, and that some of the fracturing may resemble fresh retouch (e.g., Mobley 1982). A small but growing body of literature examines how trampling affects replicated lithic assemblages, and both anecdotal and more controlled experimental evidence suggests that trampling may be an important cause of artifact edge damage in archaeological contexts. Over 30 years ago Bordes (1961a:45) suggested that prolonged trampling by herds of large mammals created certain characteristic forms of retouch on Algerian Middle Paleolithic artifacts. In 1950 he performed a replication experiment examining the role of human trampling in producing artifact edge
modification (Bordes and Bourgon 1951:17ff). He scattered 100 fresh flint flakes on a layer of flint and limestone gravel and trampled them for 15 minutes. The resulting edge modification resembled that at the Algerian sites. He reports that among the trampled flakes, some were extensively damaged, while others retained intact edges. Damage consisted of irregular, abrupt, or alternate edge modification, the blows often directed at nearly right angles to the edge, rather than delivered oblique to the edge as in normal retouch. Bordes (1961:45) later coined the term “pseudo-tools” to describe such pieces.

In a frequently cited experiment, Tringham et al. (1974) buried 10 chert flakes just below the surface of what was presumably a loam soil. These were then heavily trampled for 30 minutes by an unspecified number of people. The authors conclude that edge damage produced by this means is easily distinguished from edge wear produced by use on the basis of three criteria: (1) the location and orientation of damage scars along the flake perimeter are random; (2) trampling scars are more elongate than those produced by use; and (3) the scars produced by trampling occur on one flake surface only, that is, the surface opposite that which faced the treads. The latter observation, however, appears to be contradicted by an illustrated experimental artifact (Tringham et al. 1974:Figure 6) that exhibits damage to both faces. In a somewhat similar study, Keeley (1980) reports that four flint flakes buried in a well-worn path for a period of about one year sustained both random and clustered edge modification.

The small sample sizes in these two experiments clearly suggest the need for further examination, and the findings of Tringham et al. (1974) have not been entirely confirmed by subsequent research. Gifford-Gonzalez et al. (1985) trampled two assemblages of 1,000 obsidian flakes each, one on a loam substrate, the other on unconsolidated medium fine sand in a stabilized beach dune environment. Two people in soft-soled shoes trampled the material for two hours in each case. Although the accidental loss of much of their original experimental assemblage somewhat compromises their findings, their analysis of a limited portion of the material shows, first, that scar orientation is not random, and second, that the number of elongate scars varies with substrate.

Flenniken and Haggerty (1979) report an experiment in which obsidian flakes were knapped directly onto a matrix of loess silty loam. They were then subjected to 2,000 paces of bidirectional walking by three adults wearing soft-soled shoes. Like Tringham et al. (1974), they find no obvious pattern to the edge damage in location, size, or orientation of flake scars; however, they find that edge damage occurs on both dorsal and ventral surfaces. Pryor (1988) has reached somewhat different conclusions. In his experiment, obsidian flakes of known size classes were trampled for two hours on a substrate of sand and on a loam interspersed with gravel and a few cobbles by two people wearing soft-soled shoes. Pryor concurs with Tringham et al. (1974) that trampling can be distinguished from damage produced by utilization, and finds that flake scars resulting from trampling are sparse and randomly oriented as predicted, although he reports no specific figures. However, with Flenniken and Haggerty (1979), and contrary to Tringham et al. (1974), he finds that flake scars are not elongate and that they occur on both sides of the flakes. Having painted the two sides of each flake different colors, Pryor is in a position to note that flakes flip readily during trampling.

The most systematic study reported to date is that of Nielsen (1991), who describes a total of six trampling experiments. In five of these, bone, obsidian flakes, ceramic sherds, and fragments of wood and brick were laid out in an area of 1 m² containing different substrates and trampled by people wearing tennis shoes for 1,600 or 3,000 steps per square. A sixth experiment involved material trampled on a path for periods of three and six days. He reports complete results only for the loam substrate. Nielsen’s results are in agreement with those of Flenniken and Haggerty (1979) and Pryor (1988); he finds that flake scars resulting from trampling are sparse, isolated, occur on either face, and have no apparent preferred shape or alignment. In a series of experiments described by Shea and Klenck (1993), flint artifacts that had been used to perform various tasks were trampled in a box filled with moist sandy soil by one person wearing soft-soled shoes for periods of 15, 30, and 45 minutes. They found that trampling damage was unevenly distributed over the artifacts’ edges and that flake scars were broad rather than elongate.
Research Design and Method

Since Bordes's pioneering replication experiment, it has been clear that trampling can produce artifact edge modification that resembles retouch. However, in practice, archaeologists continue to assume that the effects of trampling on artifact edges are either negligible or that they can be distinguished readily from deliberate artifact retouch. We wished to test the proposition that the effects of artifact trampling are not negligible and that edge damage produced by trampling may convincingly mimic what archaeologists call deliberate retouch. Our experiments were intended to replicate conditions that artifacts might be subjected to after discard, and before burial, and we examined the relative contributions of differences in raw material, substrate, and artifact density to the degree and kind of edge damage.

Raw Materials and Flake Production

A fairly coarse-textured chert collected on the Balcones escarpment, near San Antonio, Texas, and a high-quality California obsidian were used. Blocks of chert and obsidian were knapped by direct percussion using quartzite and granite hammerstones with little attempt at regularity in core reduction. The chert proved fairly tough and intractable; the obsidian is easily flaked and fairly brittle, although it had been soaked in water for four days before flaking to prevent shattering. From the flakes produced we selected 1,400 flakes of each raw material, ranging in size from 3 to 7 cm in maximum dimension. The relative uniformity in size was meant to control for breakage caused by large discrepancies in flake size. The assemblages of flakes in each raw material were divided into two sets of 500 and two sets of 200 flakes and were spray-painted to facilitate recovery after trampling.

Substrates

The experimental substrates are loam and sand. The loam experimental site is at East Rock Park, New Haven, Connecticut, and the sand site at Light House Point beach, on Long Island Sound near New Haven, Connecticut (Figures 1 and 2). Both sites are roughly level and free of obstructing vegetation and stones. The loam can be more precisely described as an extremely poorly sorted sandy silt, containing <3 percent fine sand, ~15 percent medium sand, and ~5 percent coarse sand, by volume, with the remainder made up of silt- and clay-sized particles. The constituents of the coarser component are subrounded to rounded quartz grains, lithic fragments, and feldspar and mica.
crystals; many of the finer particles are more angular. The loam is compact and was moist but not wet at the time of trampling, and had neither a surface layer of unconsolidated litter as described by Nielsen (1991) for his experimental settings, nor a high proportion of rootlets and organic debris as described by Gifford-Gonzalez et al. (1985).

The sand experimental site is a storm beach above the normal high watermark. Upon excavation, two clearly defined strata were observed, an upper layer about 10 cm in thickness made up of medium to fine, dry, unconsolidated sand, and beneath it, coarser, damp, and more compact sand. More specifically, the upper unit contained <3 percent fine sand, ~87 percent medium sand, and ~10 percent coarse sand, and was medium to well sorted. Lithologically it comprised 85–90 percent subrounded quartz grains, <2 percent angular medium-sized feldspar crystals, the remainder being coarse- to fine-grained subrounded to rounded metamorphic lithic clasts. The lower sand unit is much more poorly sorted, with a larger proportion of coarse particles. It is made up of >85 percent subangular quartz grains, ~5 percent coarse, mostly angular feldspars, and ~10 percent subrounded lithic fragments, ranging up to ~20 mm in diameter. These are primarily fragments of quartzite, mica, and unidentified metamorphic rock, although some angular shell fragments also are present. Although soil penetrability was not measured at either site, the sand substrate is far less compact than the loam.

Experimental Procedure
A total of eight individual trampling runs was performed. At each of the two experimental sites, an area 3 x 3 m was laid out and raked and brushed to remove loose vegetation and large clasts. The artifacts were then placed carefully and uniformly over the central 1 m² of the cleared area (Figures 1 and 2). This square contained 200 artifacts in the low-density experiments, 500 in the high-density
runs. While these numbers may at first glance appear high, it must be kept in mind that an experienced knapper can easily produce 100 flakes in a matter of minutes. Early site descriptions may report anomalously low densities, reflecting the fact that material considered waste or débitage is ignored, if not discarded. But densities comparable to or greater than those in our experiments are common in the literature, for example, 364/m² at the Holocene site of Anagula in the Aleutian Islands (Feder 1982), 434/m³ in the Middle Stone Age level in Member 4 at Muguruk, Kenya (McBrearty 1986, 1988), 500/m² at the early Neolithic site of Ali Kosh, Iran (Hole et al. 1969), and 725/m² within the mammoth bone oval at the Middle Paleolithic site of Molodova 1 (Klein 1973). Byrd and Garrard (1990) report a staggering 20,583 chipped-stone artifacts per m³ from the Late Pleistocene site of Uwaynid 14, Jordan. This figure does not include indeterminate debitage and chipping debris, and values in excess of 10,000/m³ are common in the region for this time period.

Trampling itself was performed by two people at a time, walking at a normal pace and wearing rubber-soled shoes (Figure 2). They made switchback transects crossing the central square with each pass. No attempt was made to cover all areas of the square with equal frequency or to tread on individual artifacts deliberately. The duration of trampling was one hour for each individual experiment, but it probably resulted in more damage than normal prehistoric human activities would produce in this amount of time (cf. Gifford-Gonzalez et al. 1985:807).

For experiments on the sandy substrate, the area was excavated with shovels after trampling to a final depth of 25 cm in two spits corresponding to the natural strata. The first spit consisted of the upper 10 cm of medium to fine, dry, unconsolidated sand, and the second was composed of 15 cm of the coarser, damp, and more compact sand beneath it. For experiments on the loam substrate, large artifacts were gathered by hand and small ones swept up with brushes. The central area was then trowel scraped to a depth of 5 cm. In both cases the sediment was passed through ¼-inch mesh; recovery was nearly 100 percent on both substrates, although a larger number of small frag-
ments was recovered from the loam. All artifacts were then individually wrapped to prevent further damage during transport to the laboratory.

**Analytical Procedure**

Some flakes were broken during trampling, and this naturally increased the number of pieces in our samples. We refit where possible and included only pieces >2 cm in maximum dimension in our formal analysis. Artifacts >2 cm were classified into four categories: undamaged, edge-damaged, pseudo-tools, and broken. Pieces were considered undamaged if their edges were pristine under magnification of 10× or showed only isolated scars <1 mm in size. Edge-damaged pieces exhibit either a few isolated larger scars measuring between 2 mm and 3 mm or edge “nibbling,” that is, a number of contiguous small scars measuring between 1 mm and 3 mm. Pseudo-tools show one or more large scars (>3 mm); in most cases these scars are contiguous. Two sets, one chert and one obsidian, containing a high proportion of pieces with this type of edge damage were sorted according to the standard typology of Bordes (1961b), appropriate to a flake-based industry.

**Results**

No exact positional data were recorded for individual artifacts, as the study of artifact dispersal was not the object of the experiment. We observed, however, that in the sand artifacts quickly disappeared beneath the surface during trampling. Upon excavation they were found to be fairly widely dispersed both laterally and vertically, although more remained in the central square than outside it. Most artifacts were concentrated at a depth of about 10 cm at the contact between the surface layer of finer, looser, dry sand and the coarser, more compact, damp sand beneath it. On the loam, artifacts were much less dispersed vertically, having penetrated to a depth of only about 2 cm. These observations are very similar to those reported by Gifford-Gonzalez et al. (1985) for both the sand and loam contexts. In our experiments on the loam substrate, lateral transport along the repeated paths of the trampers produced a starlike pattern with its apex in the central densest square (see Figure 3).

All experimental sets contained broken pieces, edge-damaged pieces, and pseudo-tools (Table 1). Through breakage, trampling both increases the number of artifacts and reduces their mean size (cf. Nielsen 1991; Pryor 1988). The least change of this kind occurs in set 1 (chert, sand, low density), where the appearance of 13 fragments <2 cm increases the numbers in the original sample by 6.5 percent; the greatest change is in set 6 (chert, loam, high density), where the sample increased by 39 percent through the addition of 195 fragments <2 cm. Some small artifacts were no doubt lost during excavation at the sand site, and the figures for objects <2 cm would be inflated further if small pieces conjoined to artifacts in other categories were included.

Between 8.5 percent and 30 percent of the pieces in the trampled assemblages show minimal edge damage; between 7.5 percent and 65 percent of the pieces have the more substantial edge modification that mimics deliberate retouch and places them in the pseudo-tool category. Set 8 (obsidian, high density, loam) shows the highest proportion of pieces with modification of this kind. Pseudo-tools and edge-damaged pieces combined, including those that are broken, make up 92 percent of the assemblage.

**Formal Tools**

Many of the pseudo-tools created by these experiments so much resemble Paleolithic formal tools that they can be classified according to the standard typology of Bordes (1961b), devised primarily for the European Middle Paleolithic. We adopted a very conservative approach to the treatment of formal tools. We ruled out any whose total modified edges measured <2 cm in length, and eliminated any piece whose modification was exclusively to cortical edges. Bordes’s typology includes several categories of pseudo-tools (types 45–50) (Bordes 1953:460, Footnote 7, 1961b:45; Bordes and Bourgon 1951:6). These have abrupt or thick retouch, as well as certain kinds of alternate or bifacial retouch. All artifact classification by its nature contains a subjective element, and replicability among investigators is an ideal to strive for. Bordes’s “pseudo-tool” categories are particularly problematic, as analysts may take extrinsic factors, such as inferred depositional context, into account in their decisions. We therefore eliminated from consideration any pieces that could not easily be contained in any of
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</table>

1Includes broken pieces.
2Includes pseudo-tools and edge damaged pieces.
3Failed to compute; not included in analysis.
4% excluded from analysis.
5Not recorded.

Bordes’s standard, essential, formal tool categories, excluding types 45–49. When all such ambiguous pieces are removed, we find that substantial proportions of our assemblages can be classified as formal tools. Type 50, *pointes de Tayac*, while excluded by Bordes, is recognized as legitimate by some archaeologists and was retained in our analysis. In set 6 (chert, high density, loam), formal tools defined in this way make up 16.8 percent of the total assemblage and 46.1 percent of the pieces that we had classified as pseudo-tools. For set 8 (obsidian, high density, loam), the numbers are substantially higher: 44.4 percent of the total assemblage and 59.1 percent of the pseudo-tools. Values would no doubt be higher if less stringent criteria were applied. A sample of these pseudo-tools is illustrated in Figures 4, 5, 7, 9, and 10. For the purposes of comparison, photographs of some of the same objects are included as Figures 6 and 8.

![Figure 4. Formal tools, set 6 (chert, loam, high density): (a, b) *racloirs simples droits*, (c, d, e) *racloirs simples concaves sur face plane*, (f) *racloir double*; (g) *racloir transversal*, (h) *encoche clactonienne* with conjoining flake, (i) *encoche clactonienne*, (j, k, l) *encoche vrais*.](image-url)
When classified according to the *système* Bordes (Table 2), notches and denticulates dominate both set 6 and 8 assemblages, making up 57.1 percent of the chert tools and 88.2 percent of the obsidian tools. Notched pieces include both “Clacton” notches (*encoches clactoniennes*), in which the notch is made up of a single large flake scar (Figure 4h, i, Figure 7f, g), and “true” notches (*encoches vrais*), in which the notch itself appears to be finely retouched (Figure 4j–l, Figure 7c–e). Bordes (1961b:31) states that “pseudo-notches” produced by use or natural damage can be distinguished from deliberately made notches by the presence of crushing, but crushing is not found on...
all of our experimentally produced notched pieces. Denticulates assume a variety of forms including simple (Figure 5a–d, Figure 7h–j), transverse (Figure 7k, l), déjeté (Figure 9a–e), double (Figure 9f–i), and subcircular (Figure 9j, k). Multiple notches (Figure 7e) and combination notch and denticulate pieces (Figures 5e, f, Figure 10d–f) are common in both assemblages. Side-scrapers (racloirs) make up 32.1 percent of the set 6 tools (Figure 4a–g) and 6.4 percent of those in set 8. Pointed pieces, including perçoirs (Figure 10k, l) and pointes de Tayac (Figure 10i, j), which are essentially convergent denticulates, are present in set 8. Tool types more common to the Upper Paleolithic are found in set 6 (chert), including end-scrapers (grattoirs, Figure 5h, Figure 10g, h) and backed knives (couteaux à dos, Figure 5i).

Variables Affecting Artifact Damage
In these experiments we controlled for three vari-
ables: raw material, substrate, and artifact density. Simply scanning the results in Table 1 suggests that substrate is the most important factor affecting artifact fate. About 50 to 75 percent of the artifacts in the sets trampled on sand remained undamaged, whereas only between 2 percent and 17 percent of the artifacts trampled on loam escaped unscathed. In order to examine quantitatively the relative importance of raw material, substrate, and artifact density in determining the amount and kind of damage inflicted, we performed a series of logistic regressions on these
Table 2. Formal Tools, High-Density Assemblages Trampled on Loam.

<table>
<thead>
<tr>
<th></th>
<th>Chert</th>
<th></th>
<th></th>
<th>Obsidian</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Denticulés ordinaires, simples</td>
<td>27</td>
<td>32.14</td>
<td></td>
<td>39</td>
<td>17.73</td>
</tr>
<tr>
<td>Denticulés ordinaires, doubles</td>
<td>0</td>
<td>0</td>
<td></td>
<td>16</td>
<td>7.27</td>
</tr>
<tr>
<td>Denticulés transversaux</td>
<td>0</td>
<td>0</td>
<td></td>
<td>13</td>
<td>5.91</td>
</tr>
<tr>
<td>Denticulés subcirculars</td>
<td>0</td>
<td>0</td>
<td></td>
<td>2</td>
<td>.91</td>
</tr>
<tr>
<td>Denticulés déjetés</td>
<td>0</td>
<td>0</td>
<td></td>
<td>13</td>
<td>5.91</td>
</tr>
<tr>
<td>Denticulé en bout d’éclat</td>
<td>0</td>
<td>0</td>
<td></td>
<td>11</td>
<td>5.00</td>
</tr>
<tr>
<td>Total denticulates</td>
<td>27</td>
<td>32.14</td>
<td></td>
<td>94</td>
<td>42.73</td>
</tr>
<tr>
<td>Encoches vraies</td>
<td>8</td>
<td>9.52</td>
<td></td>
<td>34</td>
<td>15.45</td>
</tr>
<tr>
<td>Encoches clactonnienes</td>
<td>10</td>
<td>11.90</td>
<td></td>
<td>21</td>
<td>9.55</td>
</tr>
<tr>
<td>Encoches vraies, multiples</td>
<td>0</td>
<td>0</td>
<td></td>
<td>15</td>
<td>6.82</td>
</tr>
<tr>
<td>Encoches vraies en bout d’éclat</td>
<td>0</td>
<td>0</td>
<td></td>
<td>9</td>
<td>4.09</td>
</tr>
<tr>
<td>Encoches clactonnienes à dos abattu</td>
<td>0</td>
<td>0</td>
<td></td>
<td>1</td>
<td>.45</td>
</tr>
<tr>
<td>Total notches</td>
<td>18</td>
<td>21.42</td>
<td></td>
<td>80</td>
<td>36.36</td>
</tr>
<tr>
<td>Denticulés ordinaires and encoches vraies</td>
<td>2</td>
<td>2.38</td>
<td></td>
<td>12</td>
<td>5.45</td>
</tr>
<tr>
<td>Encoche vraie and racloir double convex</td>
<td>1</td>
<td>1.19</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Denticulés ordinaires and encoches clactonnienes</td>
<td>0</td>
<td>0</td>
<td></td>
<td>5</td>
<td>2.27</td>
</tr>
<tr>
<td>Denticulés en bout d’éclat and encoches vraies</td>
<td>0</td>
<td>0</td>
<td></td>
<td>2</td>
<td>.91</td>
</tr>
<tr>
<td>Denticulé ordinaire and encoche multiple</td>
<td>0</td>
<td>0</td>
<td></td>
<td>1</td>
<td>.45</td>
</tr>
<tr>
<td>Total multiple tools</td>
<td>3</td>
<td>3.57</td>
<td></td>
<td>20</td>
<td>9.08</td>
</tr>
<tr>
<td>Racloirs simples droits</td>
<td>9</td>
<td>10.71</td>
<td></td>
<td>6</td>
<td>2.73</td>
</tr>
<tr>
<td>Racloirs simples concaves</td>
<td>8</td>
<td>9.52</td>
<td></td>
<td>1</td>
<td>.45</td>
</tr>
<tr>
<td>Racloirs simples convexes</td>
<td>9</td>
<td>10.71</td>
<td></td>
<td>3</td>
<td>1.36</td>
</tr>
<tr>
<td>Racloir double</td>
<td>1</td>
<td>1.19</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Racloirs transversaux</td>
<td>1</td>
<td>1.19</td>
<td></td>
<td>4</td>
<td>1.82</td>
</tr>
<tr>
<td>Racloir d’angle</td>
<td>1</td>
<td>1.19</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total simple scrapers</td>
<td>29</td>
<td>34.51</td>
<td></td>
<td>14</td>
<td>6.36</td>
</tr>
<tr>
<td>Pointes de Toyac</td>
<td>0</td>
<td>0</td>
<td></td>
<td>5</td>
<td>2.27</td>
</tr>
<tr>
<td>Perçoirs</td>
<td>0</td>
<td>0</td>
<td></td>
<td>4</td>
<td>1.82</td>
</tr>
<tr>
<td>Perçoir and encoche vraie</td>
<td>0</td>
<td>0</td>
<td></td>
<td>1</td>
<td>.45</td>
</tr>
<tr>
<td>Total pointed tools</td>
<td>0</td>
<td>0</td>
<td></td>
<td>10</td>
<td>4.54</td>
</tr>
<tr>
<td>Grattoirs</td>
<td>0</td>
<td>0</td>
<td></td>
<td>2</td>
<td>.91</td>
</tr>
<tr>
<td>Couteaux à dos</td>
<td>2</td>
<td>2.38</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grattoirs sur éclat</td>
<td>5</td>
<td>5.95</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total Upper Paleolithic type tools</td>
<td>7</td>
<td>8.33</td>
<td></td>
<td>2</td>
<td>.91</td>
</tr>
<tr>
<td>Total tools</td>
<td>84</td>
<td>100.00</td>
<td></td>
<td>220</td>
<td>100.00</td>
</tr>
</tbody>
</table>

data using the program LogXact (Table 3). From these it is clear that substrate plays the most important role, raw material a lesser role, and artifact density the least important role in producing the major damage. For example, the odds ratios indicate that flakes trampled on loam are 13.05 times more likely than those on sand to become pseudo-tools; obsidian flakes are 2.13 times more likely than chert flakes to become pseudo-tools; and flakes trampled at high densities are 1.8 times more likely to become pseudo-tools than those trampled at low densities. The relative importance of substrate, raw material, and density in determining artifact fate remains the same when the data are examined from the point of view of the likelihood of remaining undamaged. When considering the likelihood of breakage, substrate is the most important factor, followed by raw material; artifact density did not appear to have a significant impact. In all cases the three factors act independently, and interaction among them is negligible.

**Diagnostic Criteria**

A number of features were examined to determine their usefulness in distinguishing edge damage produced by trampling from deliberate retouch.  

**Flake Scar Characteristics.** Tringham et al. (1974) report that the damage scars produced in
Table 3. Logistic Regressions of Retouch, Breakage, and Edge Damage.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta</th>
<th>S.E. (Beta)</th>
<th>p (2-sided)</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome: flakes scored as retouched</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-3.03</td>
<td>.14</td>
<td>.0000</td>
<td></td>
</tr>
<tr>
<td>Raw material</td>
<td>.76</td>
<td>.09</td>
<td>.0000</td>
<td>2.13</td>
</tr>
<tr>
<td>Substrate</td>
<td>2.57</td>
<td>.10</td>
<td>.0000</td>
<td>13.05</td>
</tr>
<tr>
<td>Density</td>
<td>.60</td>
<td>.11</td>
<td>.0000</td>
<td>1.86</td>
</tr>
<tr>
<td>Outcome: flakes scored as broken</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-2.93</td>
<td>.13</td>
<td>.0000</td>
<td></td>
</tr>
<tr>
<td>Raw material</td>
<td>.60</td>
<td>.11</td>
<td>.0000</td>
<td>1.82</td>
</tr>
<tr>
<td>Substrate</td>
<td>1.30</td>
<td>.12</td>
<td>.0000</td>
<td>3.69</td>
</tr>
<tr>
<td>Outcome: flakes scored as undamaged</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.60</td>
<td>.12</td>
<td>.0000</td>
<td></td>
</tr>
<tr>
<td>Raw material</td>
<td>-.73</td>
<td>.10</td>
<td>.0000</td>
<td>.47</td>
</tr>
<tr>
<td>Substrate</td>
<td>-3.21</td>
<td>.11</td>
<td>.0000</td>
<td>.45</td>
</tr>
<tr>
<td>Density</td>
<td>-.60</td>
<td>.11</td>
<td>.0000</td>
<td>.55</td>
</tr>
</tbody>
</table>

Note: In all cases, models with interactions were examined and the final models selected as the most parsimonious. For independent variables, obsidian, high density, and loam were scored as 1; chert, low density, and sand were scored as 0.

their experiments are elongate, randomly located and oriented, and found on one flake surface only. We tested these predictions by examining subsamples of pseudo-tools from all eight trampled sets for flake scar numbers, placement, size, and proportions. None of our samples has a median value for breadth/length ratio (B/L) that indicates elongate flake scars (Figure 11). Rather, the average flake scar in our experimental assemblages is slightly to very broad. If elongate scars are defined as those with B/L ratios ≤ .5, only 15 (7.3 percent) of a sample of 207 measured flake scars from all experimental sets can be considered elongate. We do find, however, that mean B/L is slightly less, indicating slightly more elongate scars, for the sand sample (1.23 ± .6 mm) than for the loam sample (1.6 ± .68 mm). Our obsidian flakes also have slightly more elongate flake scars than the chert flakes. Analysis of variance shows that the effects of both raw material and substrate produce significant differences for B/L ratio (p = .006 and .013, respectively). The two factors operate independently, and with additive effects, with the result that obsidian flakes trampled on sand have the most elongate scars of any experimental set. However, a low value for r (.334) indicates that this is not a finding of great consequence.

In all our experimental sets, we find that flake scars are found on both sides of the trampled flakes (Table 4), and dorsal scars slightly outnumber ventral scars in nearly all sets. Sample sizes are small for sets 1, 2, and 3, as most artifacts from these sets were repainted and recycled for use in subsequent trampling runs before this information was collected. Total scar numbers are greater for sets trampled on loam; of these, those trampled at high densities have higher ratios of dorsal to ventral scars. We did not test for true randomness for flake scar location. However, when flake scars are sparse, they appear not to show any preferential

Figure 11. Box plot of B/L ratios for flake scars measured from each experimental set. Boxes follow standard conventions: the upper and lower ends of the boxes mark the 75th and 25th percentiles; the bar crossing the box gives the median. The whiskers give the spread of the data, except that values more than 1.5 times the interquartile range are plotted as stars.
Table 4. Numbers of Dorsal and Ventral Scars by Experimental Set.

<table>
<thead>
<tr>
<th>Set</th>
<th>Raw Material</th>
<th>Substrate</th>
<th>Density</th>
<th>n</th>
<th>Total Dorsal Scars</th>
<th>Total Ventral Scars</th>
<th>Total Scars/Flake</th>
<th>Mean Scars/Flake</th>
<th>Ratio Dorsal/ Ventral</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>chert</td>
<td>sand</td>
<td>low</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>18</td>
<td>3.60</td>
<td>1.25</td>
</tr>
<tr>
<td>2</td>
<td>chert</td>
<td>sand</td>
<td>high</td>
<td>5</td>
<td>11</td>
<td>13</td>
<td>24</td>
<td>4.80</td>
<td>.85</td>
</tr>
<tr>
<td>3</td>
<td>obsidian</td>
<td>sand</td>
<td>low</td>
<td>6</td>
<td>24</td>
<td>22</td>
<td>46</td>
<td>7.67</td>
<td>1.09</td>
</tr>
<tr>
<td>4</td>
<td>obsidian</td>
<td>sand</td>
<td>high</td>
<td>24</td>
<td>95</td>
<td>89</td>
<td>184</td>
<td>7.67</td>
<td>1.07</td>
</tr>
<tr>
<td>5</td>
<td>chert</td>
<td>loam</td>
<td>low</td>
<td>30</td>
<td>276</td>
<td>184</td>
<td>460</td>
<td>15.30</td>
<td>1.50</td>
</tr>
<tr>
<td>6</td>
<td>chert</td>
<td>loam</td>
<td>high</td>
<td>29</td>
<td>208</td>
<td>55</td>
<td>263</td>
<td>9.07</td>
<td>3.78</td>
</tr>
<tr>
<td>7</td>
<td>obsidian</td>
<td>loam</td>
<td>low</td>
<td>30</td>
<td>229</td>
<td>198</td>
<td>427</td>
<td>14.20</td>
<td>1.16</td>
</tr>
<tr>
<td>8</td>
<td>obsidian</td>
<td>loam</td>
<td>high</td>
<td>30</td>
<td>508</td>
<td>332</td>
<td>840</td>
<td>28.00</td>
<td>1.53</td>
</tr>
</tbody>
</table>

When scars are frequent, they appear either clustered or to show no preferential placement. When scars are very numerous, they become contiguous, and the resulting artifacts resemble formal tools. In our experimental assemblages, flake scar orientation is decidedly unrandom, with nearly all pieces showing flake scars perpendicular rather than oblique to the flake’s edge. The proportion of oblique flake scars is small, with values ranging from 0 to only 13.3 percent of the observed scars in the eight experimental sets. This finding is in contrast with that of Tringham et al. (1974), who report oblique scars on their trampled artifacts, but it concurs with that of Gifford-Gonzalez et al. (1985), who find that more than 70 percent of the pieces in their sample show scars perpendicular rather than oblique to the flake’s edge.

**Mechanical Damage.** Bordes (1961b:45) suggests that certain forms of mechanical damage, such as crushing, polishing, or striations, imply modification to the edge by natural agents such as trampling or cryoturbation. Therefore, diagnostic criteria to distinguish trampling from deliberate retouch were sought by examining marginal crushing, abrasion, and scratches. Marginal crushing is a very slight blunting of the edge; on obsidian it takes the form of a multitude of very fine flake scars that cannot be distinguished from one another at low magnification (10x). Abrasion in the sense of actual smoothing or polishing of artifact edges, surfaces, or arêtes is very minimal in our experimental assemblages; “abrasion,” as the term is used here, refers only to the partial removal by wear of the artifacts’ coat of paint. Scratches are those observable under very low magnification (10x).

Data for mechanical damage unfortunately were gathered for sets 4–8 only (Table 5). High frequencies for mechanical damage indicate that it may be a fair indicator of trampling damage in the archaeological record. Logistic regressions performed on data from sets 5–8, all trampled on loam, are presented in Table 6. It might be predicted that obsidian is more prone to mechanical

Table 5. Characteristic of Damage Produced by Trampling.

<table>
<thead>
<tr>
<th>Set number:</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material:</td>
<td>obsidian</td>
<td>chert</td>
<td>chert</td>
<td>obsidian</td>
<td>obsidian</td>
</tr>
<tr>
<td>Substrate:</td>
<td>sand</td>
<td>loam</td>
<td>loam</td>
<td>loam</td>
<td>loam</td>
</tr>
<tr>
<td>Density:</td>
<td>high</td>
<td>low</td>
<td>high</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Sample:</td>
<td>n=25</td>
<td>n=30</td>
<td>n=30</td>
<td>n=30</td>
<td>n=30</td>
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<td>n %</td>
<td>n %</td>
<td>n %</td>
<td>n %</td>
<td>n %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical damage</th>
<th>10</th>
<th>40.0</th>
<th>10</th>
<th>33.3</th>
<th>11</th>
<th>36.7</th>
<th>22</th>
<th>73.3</th>
<th>22</th>
<th>73.3</th>
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</thead>
<tbody>
<tr>
<td>Crushing</td>
<td>15</td>
<td>60.0</td>
<td>7</td>
<td>23.3</td>
<td>13</td>
<td>43.3</td>
<td>20</td>
<td>66.7</td>
<td>25</td>
<td>83.3</td>
</tr>
<tr>
<td>Abrasion</td>
<td>19</td>
<td>76.0</td>
<td>28</td>
<td>93.3</td>
<td>NR*</td>
<td>NR</td>
<td>20</td>
<td>66.7</td>
<td>25</td>
<td>83.3</td>
</tr>
<tr>
<td>Scratching</td>
<td>0</td>
<td>0.0</td>
<td>4</td>
<td>16.0</td>
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<td>6.7</td>
<td>1</td>
<td>3.3</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td><em>Retouch</em></td>
<td>0</td>
<td>0.0</td>
<td>4</td>
<td>16.0</td>
<td>2</td>
<td>6.7</td>
<td>1</td>
<td>3.3</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*NR indicates not recorded.
Table 6. Logistic Regressions of Flake Damage.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta (Beta)</th>
<th>S.E. (Beta)</th>
<th>p (2-sided)</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome: marginal crushing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-.62</td>
<td>.27</td>
<td>.0000</td>
<td></td>
</tr>
<tr>
<td>Raw material</td>
<td>1.63</td>
<td>.40</td>
<td>.0000</td>
<td>5.10</td>
</tr>
<tr>
<td>Outcome: flake abrasion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-1.19</td>
<td>.37</td>
<td>.0000</td>
<td></td>
</tr>
<tr>
<td>Raw material</td>
<td>1.88</td>
<td>.42</td>
<td>.0000</td>
<td>6.56</td>
</tr>
<tr>
<td>Density</td>
<td>.92</td>
<td>.42</td>
<td>.029</td>
<td>2.51</td>
</tr>
<tr>
<td>Outcome: thick/alternate retouch</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-3.79</td>
<td>.74</td>
<td>.0000</td>
<td></td>
</tr>
<tr>
<td>Raw material</td>
<td>1.32</td>
<td>.58</td>
<td>.023</td>
<td>3.76</td>
</tr>
<tr>
<td>Density</td>
<td>2.02</td>
<td>.67</td>
<td>.003</td>
<td>7.52</td>
</tr>
</tbody>
</table>

Note: In all cases, models with interactions were examined, and the final models selected as the most parsimonious. For independent variables, obsidian and high density were scored as 1; chert and low density were scored as 0.

Damage than chert, and odds ratios indicate that it is five or six times more likely to suffer crushing or abrasion. Density appears to have no effect on outcome for crushing. To examine the effect of substrate, sets 4 and 8, both obsidian trampled at high density, can be contrasted. G-tests (Sokal and Rohlf 1981) indicate that artifacts trampled on loam are significantly more likely than those trampled on sand to suffer crushing (G = 6.3; p = .016). Artifacts also are more likely to become abraded, although this result is not statistically significant (G = 3.7; p = .052).

**Pseudo-retouch.** Three distinctive types of "pseudo-retouch" were examined: abrupt, steep, and thick/alternate. Abrupt pseudo-retouch, as the term is used here, is synonymous with step flaking. Steep pseudo-retouch is that in which the edge angle approaches 90°. Thick/alternate pseudo-retouch is defined by Bordes (1961b) as "retouch" affecting the thickness of the flake and delivered from alternate sides of the artifact. Extensive thick/alternate pseudo-retouch results in a distinctly sinuous edge that is a diagnostic feature of Bordes's "pseudo-tool" category.

As can be seen in Table 5, abrupt retouch is not particularly frequent in any of our trampled sets for which data were recorded. Logistic regression analysis of data from sets 5–8 (Table 6) shows that neither density nor raw material has a significant effect in predicting whether an artifact will exhibit abrupt or steep pseudo-retouch. Substrate, though, seems to have a pronounced effect. A G-test comparing sets 4 and 8 (obsidian, high density, sand vs. loam) shows that artifacts trampled on loam are significantly more likely to show steep pseudo-retouch than those on sand (G = 18.2; p < .0001). Thick flakes appear to be more likely to be steeply "retouched" than thin ones. Measured subsamples of pseudo-tools from sets 7 and 8 contain a fairly high proportion of pieces with steep pseudo-retouch. They have a mean thickness exceeding 10 mm, and a difference of means test (Bailey 1959) shows that they differ significantly from the total sample of flakes from these assemblages, whose mean thickness is < 10 mm (d = 3.20; p = .0031).

Thick/alternate pseudo-retouch is absent from set 4, trampled on sand, but is found on between 4 and 40 percent of artifacts in sets 5–8 trampled on loam (Table 5). Logistic regression analysis shows that both density and raw material significantly affect outcome for this type of damage (Table 6), but a G-test contrasting sets 4 and 8 (both obsidian, high density) shows that substrate has a very marked effect. Artifacts trampled on loam are significantly more likely to show thick/alternate pseudo-retouch than those trampled on sand (G = 17.3; p < .0001). Thus it would appear that as a criterion for diagnosing trampling damage, thick/alternate pseudo-retouch is not ideal. Fragile raw materials trampled at high densities on impenetrable substrates, like set 8, may show abundant damage of this kind, but it may be rather infrequent in other contexts.

**Discussion**

A number of these results are at odds with previous findings and have implications for the interpretation of some classic European Paleolithic industries.

**Importance of Substrate**

Archaeologists are rightly suspicious of lithic artifact edge modification when it is found in high-energy depositional regimes. Harris (1978) and Bar-Yosef (1989) have pointed out that the amount of apparent retouch observed on flakes can vary directly with depositional environment, and Flenniken and Haggerty (1979) predict a higher degree of damage to trampled artifacts on coarse-grained substrates. Our results are important because they show that edge modification to artifacts trampled on fine-grained sediments can also
be very severe. In our experiments, most damage occurs when artifacts are trampled on loam, a fine-grained, relatively impenetrable substrate, and it appears that much of the damage is caused by the impact of artifact on artifact. Like Nielsen (1991), we conclude that it is penetrability, rather than grain size, that is important in this context. Unfortunately, while grain size in archaeological sediments can be directly observed, substrate compaction at the time of occupation can only be inferred.

High artifact density, while not as important as substrate, also increases the likelihood of impact damage. In unconsolidated sand, flakes disperse rapidly, resulting in fewer impacts and less damage. However, when a substrate includes clasts of pebble size or above, the impact damage of angular substrate particles and scars inflicted by other artifacts are probably indistinguishable. Of course, while our experimental conditions approximate those encountered at some Paleolithic sites, most archaeological deposits contain additional cultural and natural debris of different sizes, shapes, and resistances. When subjected to trampling, they can all be expected to play some part in lithic artifact damage.

It is a somewhat unexpected finding that raw material plays a less important role in determining artifact fate. Archaeologists might expect obsidian, which is easily flaked and fairly brittle, to exhibit damage of this kind. While obsidian does consistently show more damage than the tougher chert, substrate and artifact density make more important contributions to the amount and kind of artifact damage. It seems likely that experiments employing good-quality European flint, in which most western European Paleolithic artifacts are made, would produce flakes showing an amount of damage intermediate to that shown by the obsidian and chert in our experimental assemblages. Very intractable rocks, such as the lavas found in many African Stone Age sites, would probably show less damage after trampling than the material described here, but these results suggest that the "nibbling" edge damage found on so many lava artifacts is of no behavioral significance.

Diagnostic Criteria

Thick/alternate pseudo-retouch is considered by Bordes (1961b) to be characteristic of assemblages damaged by trampling or other postdepositional agents. Though it is sometimes a useful indicator, we did not find this feature ideal for diagnosing trampling damage in all contexts. It is found on 4–40 percent of artifacts trampled on loam, but we observed no thick/alternate pseudo-retouch on our small sample of artifacts trampled on sand. Thus, assemblages trampled on impenetrable substrates may show a fairly high frequency of this kind of damage, but it may be rather infrequent in other contexts. The disturbing implication of this finding is that using current formal criteria, it may be impossible to distinguish with confidence between deliberate retouch and postdiscard, nondeliberate artifact damage. We therefore attempt to codify here a number of features that may be useful in distinguishing artifact assemblages that have been subjected to trampling from those that have not.

Tringham et al. (1974) observed edge damage on only one side of trampled buried flakes. In our experiments, where artifacts were free to flip during trampling, the resulting damage is found on both sides of the flakes. In most archaeological lithic assemblages, dorsal retouch is more frequent than ventral retouch. Artifact typologies reflect this fact, and it is assumed to be of cultural, stylistic, or perhaps functional significance. Interestingly, however, dorsal scars consistently outnumber ventral scars in our assemblages, and this remains to be explained. An unconscious, consistent preferential face-up or face-down placement of flakes by the experimenters before trampling is a possibility that cannot be discounted. However, perhaps a better hypothesis, not tested here, implicates qualities inherent in flake geometry itself. On impenetrable substrates, artifacts may consistently come to rest with either their dorsal or ventral surfaces uppermost, and the relative steepness of the dorsal face may invite fracture, both natural and artificial.

We did not find randomness of scar location a useful descriptive criterion for trampling damage. Rather, damage scars appear to show no preferential location when they occur in low numbers, but when they are numerous they become contiguous, and the resulting artifacts resemble formal tools. Neither did we find that scars resulting from trampling were elongate as predicted by Tringham et al. (1974); rather, scars are consistently broad. We did find, however, with Gifford-Gonzalez et al. (1985), that trampling on sand produces greater numbers of elongate scars than trampling on loam, probably the
result of free impact among the flakes, as opposed to the effects of compression. We also confirm the finding of Gifford-Gonzalez et al. that scars do not show a random orientation, as predicted by Tringham et al. (1974), but rather that they show a persistent preferential alignment perpendicular to the flake edge under all experimental conditions.

Breakage of trampled artifacts increases sample size and reduces mean artifact dimensions. Bordes (1961b) suggests crushing and striations as indicators of artifact damage by trampling or other causes, and we find that mechanical damage, including crushing, abrasion, and scratches, occur at fairly high frequencies among the trampled artifacts. Shea and Klenck (1993) also detect striations and abrasive tracks on the eminent portions of their trampled flakes, primarily on the bulb and on dorsal ridges. They call these “scuff marks” and attribute them to the action of grit embedded in the trampler’s footwear. This kind of damage may be a fair indicator of trampling damage in the archaeological record, although by no means did all of our trampled artifacts show macroscopic signs of abrasion, crushing, or scratching.

The artifact features described here are macroscopic or macromorphometric only. Shea and Klenck (1993) found that trampling removed some traces of use wear by microfracture of the edge, and it created wear that can be mistaken for traces of use wear produced by cutting, scraping, or engraving medium to hard materials such as wood, bone, or hide. While not documented as systematically as other features in our analysis, both abrasion and scratching visible at low magnification (10×) were detected on our trampled artifacts. Flenniken and Haggerty (1979) suggest that microscopic analysis of use-wear polish may be the only reliable means of distinguishing deliberate from nondeliberate lithic edge damage. However, microwear is not preserved on all raw materials in all archaeological contexts, analysis of all artifacts in large samples is not feasible, and use-wear studies are not without methodological problems of their own. Where microwear analysis is possible, though, abrasion and scratches may provide a useful indicator of trampling damage.

Implications for the Denticulate Mousterian

Much of the edge damage we observed on our trampled flakes mimics formal retouch, and many of our pseudo-tools can be classified as formal tools according to the standard typology of Bordes (1961b). Our experimental assemblages include a full range of Middle Paleolithic mimics, including many notched and denticulate forms, as well as some Upper Paleolithic types. Tool form imposed by retouch is usually interpreted as the result of either style or function. In other words, shape is thought to be designed by the maker to encode messages of group identity (Wobst 1977), to reflect historically determined styles (Sackett 1982), or to perform a specific task. The standard typology of Bordes (1961b) for the Middle Paleolithic, while considering some other aspects of artifact technology, primarily rests on characteristics of retouch in defining implement types. Samples from different Middle Paleolithic assemblages in southwestern France contain different proportions of the various scraper forms, and this ultimately led Bordes to define his five Mousterian groups: Typical, Quina, Ferrassie, Denticulate, and Mousterian of Acheulian Tradition, or MTA. (Bordes 1961b, 1966, 1968, 1973, 1981; Bordes and de Sonneville-Bordes 1970). Bordes regarded these archaeological groupings as representing social groups, “tribes,” or traditions, while Sally and Lewis Binford argued that they represented activity variants (Binford 1968, 1971, 1973; Binford and Binford 1966, 1969). While function is no doubt a contributing factor in the design of some artifact types, the discovery that Ferrassie, Quina, and MTA are consistently temporally distinct (Mellars 1970, 1986, 1988, 1996; Valladas et al. 1986) has definitively established that artifact function alone cannot explain all Mousterian industrial variability. Mellars (1996) has argued convincingly that demographic factors, social isolation, environmental change, and technological convergence can explain much of the variability seen in the European Middle Paleolithic.

Many of the observed differences among European Paleolithic assemblages no doubt reflect genuine ancient social and economic realities. However, microwear analysis and replication experiments have highlighted the inadequacies of a typological approach. The presence of retouch itself is required for inclusion in the formal tool category, yet traces of use wear found on unretouched “waste” flakes from Plio-Pleistocene Africa (Keeley and Toth 1981) and Middle Paleolithic
Europe (Beyries 1988) show that they were used as implements. Replication experiments suggest that many of the scraper types of Bordes, particularly those with Quina retouch, are not discrete target end-products, but rather represent stages in artifact resharpening (Dibble 1984, 1988a, 1988b; Rolland 1977; Rolland and Dibble 1990; Verjux 1988).

The frequency of notched and denticulate forms in our experimental assemblages indicates that they especially must be approached with wariness when encountered in archaeological contexts. Notches and denticulates are the hallmarks of Bordes’s Denticulate Mousterian, and European Middle Paleolithic tool assemblages considered to belong to the Denticulate Mousterian usually contain about 20–40 percent of these types (Bordes 1962). Our experimental assemblages contain 57 percent (chert) and 88 percent (obsidian) notches and denticulates. Bordes (1961b:31) himself warns that notches and denticulates can easily be confused with the products of utilization, and for him and Mellars the Typical and Denticulate Mousterian have less reality than the other variants (Bordes 1977, 1981; Mellars 1996). This impression is strengthened by the fact that the Denticulate and Typical Mousterian are less well constrained temporally (Mellars 1986, 1996).

However, Mellars (1996:342) accepts that functional differences can account for some of the difference between Typical and Denticulate Mousterian assemblages in southwestern France. Notches and denticulates are usually considered products of deliberate design (e.g., Kantman 1970a, 1970b), and they are often ascribed a woodworking function (Binford and Binford 1966, 1969; Bordes 1961a; Clark 1964; Rolland 1981). While traces of use wear apparently resulting from woodworking have been observed on some Middle Paleolithic notched and denticulate tools (Beyries 1988), sample sizes are fairly small. Rolland and Dibble (1990) regard denticulates as notches that have been further retouched. That is, pieces with a single notch are transformed into denticulates by the addition of further notches. They thus relate the ratio of denticulates to notches to the intensity of site occupation (Dibble and Rolland 1992).

We would caution that many notched and denticulate tools found in archaeological contexts may not have been produced deliberately, but instead may be a byproduct of human trampling. Mellars (1996) has emphasized the low frequency of racloirs, and the absence of certain fossiles directeurs, such as handaxes or backed knives, in the Denticulate Mousterian, and we would especially urge prudence in the interpretation of assemblages containing notches and denticulates but few other formal tools. The “microdenticulates” described by Bocquet (1980) resemble pieces in our edge-damaged category, and it seems highly likely that they are the product of trampling or some other natural process. Our results certainly imply that a critical reexamination of the Denticulate Mousterian is in order.

While deliberate retouch is of course an important aspect of artifact design in many industries, it is best viewed as merely one step in a long chain of behaviors (Boëda et al. 1990; Geneste 1988, 1990; Inizan et al. 1992; Kuhn 1991, 1995; Mellars 1996; Toth 1991). Especially in samples with few authentic retouched tools, the effect of trampling and other processes can contribute substantial “noise” to any typological analysis, and conclusions about economic activities, social organization, or cultural affinities must be made with caution. It may be that other links in the chain of artifact manufacture, like raw material procurement or blank production, may furnish more reliable information about past human behavior than retouch in many prehistoric contexts.

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