## Pressure Blades and Total Cutting Edge: An Experiment in Lithic Technology

Abstract. *Pressure techniques were used to remove 83 blades from a preformed obsidian core weighing 820 grams, yielding 17.32 meters of acute cutting edge. The blades represented 91 percent of the original weight (2.1 centimeters of acute cutting edge per gram of original material), thus demonstrating the efficiency of the pressure-blade techniques for the production of acute cutting edges.*

During the Idaho State University 1971 Summer Flintworking School (funded by the National Science Foundation and directed by Dr. E. H. Swanson and D. E. Crabtree) we performed an experiment to investigate the total length of blade cutting edge that could be derived from a polyhedral core. Both acute (blade edge) and obtuse (ridges formed by intersections of dorsal scars) cutting edges were measured. Pressure techniques were used to remove the prismatic blades from the obsidian core; the experiment took 2½ hours from start to finish.

The core (Fig. 1a) was a mottled red-brown and black obsidian from Glass Buttes, Oregon, sawn into a block almost square in cross section (5.8 by 6.0 cm at the platform) which tapered slightly toward the distal end. The maximum height of the core was 12.7 cm. The distal end, or tip, was irregularly conical in shape. Sawing the top created a flat platform with a frosted or ground appearance. An advantage of texturing the platform surface by sawing or grinding is the decreased likelihood that the pressure tool will slip prematurely and damage the core (*1*).

The core was held firmly in a vice made of two pine boards [2 by 4 feet (61 by 122 cm)] which were spread and held apart at the far end by a cross brace. The pressure tool, a chest crutch, is the same as that described by Crabtree (*2*). It was used to remove all but two of the blades. These two blades, those at two corners of the core were removed with a hardwood pressure tool. The tool was approximately 60 cm in length and 3 cm in diameter, with a rounded end. The blades removed with the wooden tool had small and diffuse bulbs with accented lips, and no "eraillure" (bulbar) scars. Blades removed with the chest crutch had larger bulbs, smaller lips, and more eraillure scars.

The procedures we used in pressure blade removal are largely those described by Crabtree (*2*). The overhang left on the edge of the core platform by the detachment of the previous blade was removed with a copper-tipped pressure tool. Removal of the overhang decreases the amount of the platform surface removed with the blade. It is not a necessary procedure in pressure blade removal, but it assists one in placing the pressure tool accurately above the core ridges which become the dorsal ridges of the blade. Overhang removal also decreases the probability of placing the tool too close to the edge, applying force, and crushing the platform instead of removing a blade. The platform surface was usually ground lightly in the area of the proposed blade to provide purchase for the tool. The crutch tip was seated on the platform, and then downward and outward pressure was applied to detach the blade.

Certain problems were encountered during blade removal, each requiring a different strategy to overcome the difficulty. One attempt at blade removal failed owing to the fact that insufficient force had been applied for the size of the platform and the intended blade. The force did create a bulbar fracture 1 cm deep at the proximal end without actually removing any material from the core. Successful recovery was achieved by seating the pressure tool above two ridges 1 cm to the left of the previous contact point, taking a relatively large platform (0.3 by 0.15 cm), and removing most of the fractured proximal area along with the complete blade (Fig. 1e). The blade carried two platforms and two bulbs, but examination of the compression rings and fissures on the ventral surface unequivocally indicate fracture of the blade itself deriving from the second platform. Identification of this recovery technique in archeological specimens should not be difficult.

In general, blade removal from a pressure core in which the angle between the platform and the core face exceeds 90° becomes more difficult, particularly in terms of firm seating of the pressure tool. Therefore, to avoid the problem of a core too thick at the distal end, blades were removed which curved under at the core tip, thereby being thicker at the distal than at the proximal end. Recovery in this case is accomplished by removing more mass from the distal than from the proximal area of the core.

A similar kind of problem is presented by material projecting laterally beyond the curvature of the core face. Blades will often hinge or step fracture off at this mass, instead of carrying under it, thus creating a greater problem. Twice during the process of blade removal, small irregular masses were removed from the distal portion of the core by seating a tool directly on a projecting portion of the mass and using indirect percussion or pressure. Hinge fractures on the core face may often be removed in the same manner, or by percussion or pressure removal of a flake or blade from the distal end which eliminates the

Table 1. Summary of weights and measures.

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|---|---|
| Original core: | |
| | Weight, 820 g |
| | Length, 12.7 cm; width, 6 cm; thickness, 5.8 cm |
| Exhausted core: | |
| | Weight, 50 g |
| | Length, 8.2 cm; width, 2.7 cm; thickness, 2.1 cm |
| | Platform length, 1.1 cm; thickness, 0.5 cm |
| Debitage: | |
| | Weight, 24 g |
| Blades (83): | |
| | Weight, 74 g (91 percent of original weight) |
| | Total length, 8.66 m |
| | Total acute cutting edge length, 17.32 m |
| | Total obtuse scraping edge length, 14.30 m |
| | Mean blade length, 10.4 cm; range, 6.2 to 12.7 cm |
| | Mean blade width, 1.53 cm; range, 0.8 to 2.4 cm |
| Ratios: | |
| | 3.9 cm, cutting and scraping edge length per gram of original material |
| | 2.1 cm, cutting edge length per gram of original material |
| | 2.3 cm, cutting edge length per gram of blades |

hinged mass. Hinge fractures occasionally can be removed by seating the pressure tool on the platform above the hinged mass and removing a relatively large blade. Similarly, two blades may be detached side by side, each of which removes half of the hinged mass along its inner margin.

Unfortunately, the obsidian core used in this experiment was not uniformly vitreous. A zone with many phenocrysts or pumiceous inclusions and sufficient flow structure to inhibit smooth fracture was encountered in the midsection of the core. Therefore, blades were removed that were wider and thicker than would have been necessary with a better quality obsidian, thus decreasing the ratio of cutting edge to mass. For this reason, the results of this experiment must be considered conservative.

Two errors were made by slight misapplications of force. In two cases too much force was directed downward relative to the outward force, resulting in blades that plunged inward and removed the distal ends of the core (Fig. 1f). The fracture path of one of these plunging or "outrepassé" (*3*) blades seems to have been affected by vice compression stresses. Closer study of plunging blades on vice-held and otherwise-supported cores may yield criteria for the identification of holding procedures of past technologies.

In summary, 83 blades weighing 746 g (91 percent of the original weight) were produced from an original core weighing 820 g (Table 1). Thirty-three percent of the blades were triangular in cross section, whereas 67 percent were trapezoidal in cross section. Twenty-four grams of "debitage" were produced, consisting of platform overhang and small flakes detaching from the above-mentioned projecting masses. The exhausted core weighed 50 g, representing only 6 percent of the original material.

The total length of acute cutting edge was 17.32 m, or 2.1 cm of acute cutting edge for every gram of original material. Edge length was calculated by measuring the total blade length (8.66 m) and then doubling the measurement to account for both blade edges.

On a suggestion from Crabtree, the lengths of the obtuse edges were also measured. Obtuse edges, the ridges formed by the intersection of two scars on the dorsal surface of the blades, are surprisingly effective in scraping wood or bone. A total length of 14.30 m of obtuse scraping edge was produced. The exhausted core, with nine major blade scars and a length of 8.2 cm, has 70 cm of usable obtuse edge.

The ratio of the length of the cutting edge to the weight of the blade may have interesting applications in the analysis of ancient technologies. The most convenient ratio is the ratio of the cutting edge length to the weight of the blades (instead of the ratio of the edge length to the weight of all original material), for the recovery of contemporaneous cores, blades, and debitage is rare in archeology. This ratio is easily computed by weighing a large sample of blades, placing them end to end on a long table and measuring the total edge length, and then dividing the length by the weight.

Maximization of the ratio of the cutting edge length to the weight may be an index of the scarcity of obsidian in the aboriginal situation. For example, the prismatic blades in the Maya Lowlands during the Classic period (A.D. 300 to 900) are consistently thinner and narrower than the blades we produced. The ratio of cutting edge length to blade weight is quite high, probably because obsidian had to be transported over long distances (often over 300 km). However, at Chalchuapa, El Salvador, only 50 km from a large obsidian outcrop, the prismatic blades are comparable to those described in this report.

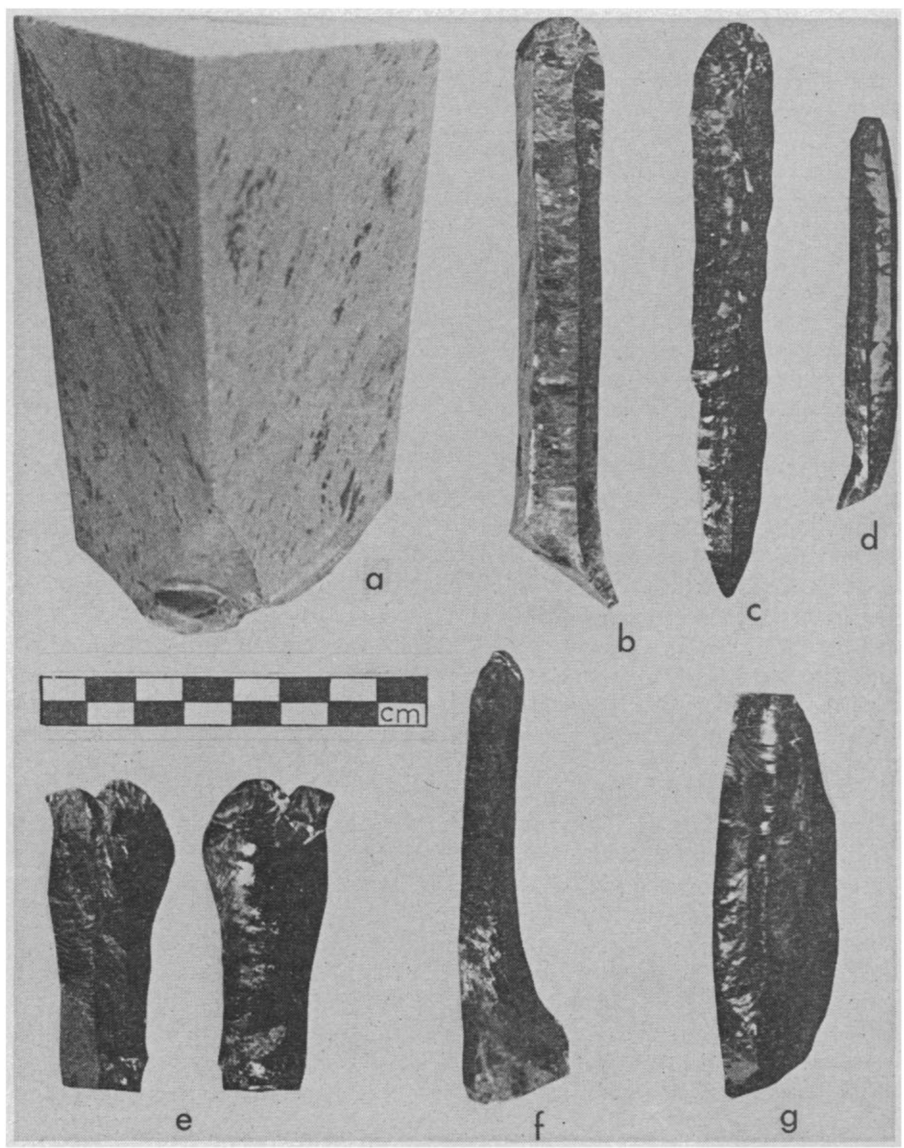


Fig. 1. The initial core and the exhausted core with blades removed: (a) the sawn obsidian core; (b–d) three pressure blades [blades in (b) and (d) are trapezoidal in cross section; the blade in (c) is triangular]; (e) dorsal and ventral views of the double-bulbed blade; (f) plunging blade that removed the core tip; (g) exhausted core.

Variation in procedures and techniques necessary to overcome the mistakes described here and by Crabtree (*2*) should be investigated in archeological samples. Both may prove to have ethnic or temporal significance in ancient technologies.

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**References and Notes**

1. A sawn core was used instead of a percussion preformed core for convenience and control. The roughened platform surface decreased the amount of grinding performed before the pressure tool was seated, and the straight edges of the core facilitated uniform blade removal. Also, the core fit snugly into the vice. Both of us have preformed cores by percussion from naturally occurring obsidian cobbles and have removed pressure blades from those cores. In particular, we have successfully duplicated archeological specimens of Mesoamerican preformed cores such as that illustrated by J. Graham and R. Heizer [*Contrib. Univ. Calif. Archeol. Res. Facil.* **5**, 123 (1968)].
2. D. Crabtree, *Amer. Antiquity* **33**, 452 (1968).
3. J. Tixier, *Typologie de l'Épipaléolithique du Maghreb* (Arts et Métiers Graphiques, Paris, 1961).

23 August 1971; revised 19 November 1971

## Spiral Waves of Chemical Activity

Abstract. *The Zhabotinsky-Zaikin reagent propagates waves of chemical activity. Reaction kinetics remain to be fully resolved, but certain features of wave behavior are determined by purely geometrical considerations. If a wave is broken, then spiral waves, resembling involutes of the circle, appear, persist, and eventually exclude all concentric ring waves.*

Zaikin and Zhabotinsky reported (*1*) the spontaneous appearance of periodic structure in an initially homogeneous fluid in a gradient-free environment—a "dissipative structure" (*2*), of chemical rather than hydrodynamic origin. In this aqueous solution, phenanthroline catalyzes the oxidative decarboxylation of malonic acid. The reaction oscillates with a period of several minutes, turning from red to vivid blue where phenanthroline is reversibly oxidized. Pseudo waves (phase gradients in bulk oscillation) sweep across the reagent at variable speed. In addition, blue waves propagate in concentric rings at fixed velocity from isolated points (pacemaker centers) with a period shorter than the period of the bulk oscillation. Unlike pseudo waves, these waves are blocked by impermeable barriers. They are not reflected. They are annihilated in head-on collisions with one another. The outermost wave surrounding a pacemaker is eliminated each time the outside fluid undergoes its spontaneous red-blue-red transition during the bulk oscillation. Because of uniform propagation velocity and mutual annihilation of colliding waves, faster pacemakers control domains which expand at the expense of slower ones: each slow pacemaker is eventually dominated by the regular arrival of waves at intervals shorter than its spontaneous period.

I have slightly altered the Zhabotinsky-Zaikin reagent to retain propagating excitability while suppressing spontaneous bulk oscillation (*3*). If this altered reagent is splattered into isolated droplets clinging to a glass surface, a very few contain pacemaker centers at first. The rest remain red for ¼ to ½ hour before they turn transiently blue.

Spontaneously generated pacemaker centers seem to arise at nuclei on the air-liquid or solid-liquid interfaces. Their periods are seldom very regular and range from several minutes to ¼ minute.

At 25°C in liquid 1 mm deep blue waves propagate about 6 mm/min. They run faster in the meniscus, where the liquid is deeper, and slower when crossing a shallow 0.1 mm deep or less, and when close behind a preceding wave. A blue wave never overtakes another from behind. The mutual annihilation and sharp cusps resulting from oblique collision show that the reagent is inexcitable immediately behind a wave.

This nonoscillating reagent was prepared in order to test an argument that, because concentration isobars in a two-dimensional continuum are closed rings (like the potential contours of electrostatics or the level contours of cartography) and a wavefront is a concentration isobar, no stable wave could arise which has a free end—for example, a spiral wave. Though the argument is specious because, as Fig. 1C shows, a spiral wave need not contain a terminating isobar, its *conclusion* seems correct in the sense that spiral waves never arise spontaneously from homogeneous initial conditions (it is difficult to imagine how an isolated nucleus *could* induce a spiral). But more importantly, it led to the rediscovery (*4*) of spiral waves of chemical activity induced by hydrodynamic flow in the medium.

To induce such waves (as well as a diversity of less stable forms) it is only necessary to briefly tilt the dish in which waves are propagating in a thin layer. Where flow parallels the wavefronts, it has no effect; but a flow component along the direction of propagation mixes phases. An elaborate morphogenesis ensues in which segments of blue waves vanish. Near each free end is a center around which the remaining blue half-line propagates, winding into a spiral, as in the development of crystal growth spirals from a screw dislocation's line of emergence (*5*).

The eventual geometry of the spiral seems independent of its (still unresolved) chemical kinetic basis, for it can be calculated from the observed symmetry as follows. We ask, "Is there a wave shape, described in polar coordinates as $\theta$ ($\rho$), for which rotation and time-translation are interchangeable?" Taking the wavelength and rotation period as units of space and time, we require that propagation normal to itself at unit velocity during any interval must be equivalent to rotation through an angle $2\pi t$ radians. In differential terms, each segment of such a curve moves through a distance $dx = dt$ at angle $\phi$ to the radius normal (Fig. 1A). Hence

$$d\rho/\rho d\theta = \tan\phi \qquad (1)$$

and

$$dt/\rho d\theta = \sin\phi \qquad (2)$$

Eliminating $\phi$ between Eqs. 1 and 2, and interchanging $dt$ with $d\theta/2\pi$, we obtain the differential equation

$$(2\pi\rho)^2 = 1 + (\rho d\theta/d\rho)^2 \qquad (3)$$

The solution of Eq. 3, for $2\pi\rho \geqq 1$, is

$$\pm\,\theta(\rho) = [(2\pi\rho)^2 - 1]^{1/2} - \cos^{-1}(1/2\pi\rho) + c \qquad (4)$$

This is an involute of a circle, constructed by revolving a pen around a cylindrical core of unit circumference, to which it is tethered by an unwinding string (Fig. 1B). At $\rho \gg 1/2\pi$, it approximates an Archimedes' ("phonograph groove") spiral, $\rho = \pm\,\theta/2\pi$.