

# *Microblithic Technology in Northern Asia: A Risk-Minimizing Strategy of the Late Paleolithic and Early Holocene*

Robert G. Elston  
Silver City, Nevada  
and

P. Jeffrey Brantingham  
University of California, Los Angeles

## ABSTRACT

**Microblade technology was important in hunter-gatherer adaptations throughout northern Asia from the late Pleistocene through the Pleistocene/Holocene transition and beyond. To date, most studies from the region are concerned with origins, technological lineages, and culture history. In contrast, we direct attention to issues involving the role of microlithic technology in adaptive strategies and problem solution among north Asian hunter-gatherers by looking at artifact design and risk analysis. First we discuss the function of Asian microblades and outline the general costs and benefits of organic points with microblade insets over simple organic points and flaked stone points, as well as the relative advantages of wedge-shaped and split-pebble microcores in terms of the Z-score model. We conclude with a review of the role of microlithic technology as a risk-minimizing strategy of Arctic and sub-Arctic large-game hunters in northern Asia and suggest further lines of inquiry.**

**M**icroblade technology was important in hunter-gatherer adaptations throughout northern Asia from the latter part of the late Pleistocene through the Pleistocene/Holocene transition and beyond (Chard 1974; Chen 1984; Chen and Wang 1989; Derev'anko 1998; Gai 1985; Goebel 1995; Goebel et al. 2000; Goebel and Slobodin 2001; Hoffecker et al. 1993; Kobayashi 1970; Kuzmin and Orlova 1998; Lu 1998; Seong 1998). To date, researchers in the region have focused primarily on issues of culture history, in which questions of culture origin and typology are foremost (Seong 1998). Consequently, we are faced with a welter of type lists, divided and subsumed into archaeological cultures that never quite account for everything—always some assemblage or date falls outside the general pattern. The failure of the archaeological record to conform to such categories is not a reflection of our excavation or typological skills.

Rather, it is the inevitable result of variability in past human behavior that is not categorical, but situational. While the distribution and variability of microlithic technology remain important variables to track, we direct attention to issues involving the role of microlithic technology in adaptive strategies. In other words, what were the major problems microlithic technologies solved for north Asian hunter-gatherers? Answering this question will help explain the emergence, spread, and persistence of microlithic technology in northern Asia.

We approach the question from the vantage point of artifact design (Bamforth and Bleed 1997; Bleed 1987; Ellis 1997; Knecht 1993, 1997) and risk analysis employing the Z-score model (Bettinger 1991; Stephens 1981; Stephens and Charnov 1982; Winterhalder et al. 1999). First we discuss the function of Asian microblades and outline the general costs and benefits of three as-

pects of microlithic technology: (1) the advantages of organic points with microblade insets over simple organic points and flaked stone points, (2) the relative efficiency of biface and microblade production, and (3) the relative advantages of wedge-shaped and split-pebble microcores in terms of the Z-score model. We conclude with a review of the role of microlithic technology as a strategy to cope with increasing variability in late Pleistocene environments of northern Asia and, finally, suggest further lines of inquiry.

### The Function of Asian Microblades

Late Paleolithic Asian microlithic technology was employed to produce stone insets for the margins of composite tools made of organic materials such as bone, antler, and ivory. No Late Paleolithic organic components of composite weapons have been recovered in China, but Late Paleolithic examples of inset projectile points are known from Siberia (Chard 1974:fig. 1.16; Derev'anko 1998:figs. 87, 127). Both composite points and knives have been recovered from Neolithic sites in Siberia and northeast China (Chard 1974:figs. 2.14, 2.16; Guo 1995:fig. 1.11; Lu 1998:92). Modified, end-hafted microblades were also sometimes used as scrapers, drills, knives, and projectile points (Elston et al. 1997; Gai 1985; Lu 1998:92; Madsen et al. 1998). There is no evidence that inset tools were ever used as sickles in the Chinese Neolithic, where this function was performed by serrated implements of ground stone, bone, or shell (Chang 1986:figs. 49, 52, 126; Shih 1992:figs. 8, 9; Underhill 1997:fig. 4).

Thus, we follow Lu (1998) and others in assuming that most Asian pre-Neolithic microblades were intended to be used as marginal insets for projectile points made of bone, antler, or ivory. In this chapter, we refer to such points without insets as *organic points* (Knecht 1997) and to organic points with insets as *inset points*. The costs and benefits of inset points are best understood in comparison with the alternatives: simple organic points and flaked stone points.

### Performance of Organic and Flaked Stone Points

The performance characteristics of organic and flaked stone points are known from experimental replication and use, and as reflected in the ethnographic record. Both aspects have been covered recently in papers by Heidi Knecht (1993, 1997) and Christopher Ellis (1997). Their findings are summarized briefly as follows (Table 8.1).

Flaked stone points are relatively fragile and often fail catastrophically in use. Breakage is particularly common when they hit the ground or impact trees or rocks. Importantly, stone points apparently become brittle and easily damaged in severe cold. Spears and arrows with stone points are composite weapons in which the stone component is expendable (Bamforth and Bleed 1997:129) and probably expected to fail. Some ethnographic hunters believe that stone points are more lethal when they break up on penetration, because the fragments increase tissue damage and bleeding. Compared to the costs of fabricating shafts, with their nocks or sockets, fletching, and hafts, flaked stone points are cheap and quick to make. The stone-tipped projectile is designed to allow replacement of a damaged point without having to create an entirely new weapon. The use of a foreshaft may offer additional protection to the main shaft, as well as increased ease in point replacement. However, making foreshafts for stone points and fitting the points to them are additional costs in manufacture, and the use of a foreshaft produces a weaker weapon than one with a solid shaft.

Organic points are made by splitting the bone or antler and shaping it by scraping and grinding. Organic points are more durable than stone points, less likely to break in use, and more easily repaired if dulled or broken. The time required to make an organic point is greater than that for most flaked stone points. However, organic points have longer use-lives, and one may spend more time making a series of expendable stone points than making one organic point (Knecht 1997). Organic points cause less lethal wounds than stone points with their sharp cutting edges that promote tissue damage and bleeding.

As summarized in Table 8.2, Ellis (1997) has evaluated the factors influencing choice of stone or organic points in a survey of over 100 ethnographic cases. He found that stone arrow and spear points are used almost exclusively for large and dangerous game (bears and large herd animals) and in warfare where killing the enemy is the object. However, the use of thrusting spears with stone points tended to be limited to situations in which there was little danger to the user or in which a number of replacement weapons were available. Organic points were used when wielding thrusting spears against smaller herd animals, against dangerous animals when no replacement weapons were available, when multiple thrusts were to be given in warfare, on arrows used in cold weather (when stone points are brittle and easily broken), and when throwing spears in heavy underbrush.

Table 8.1. Performance characteristics of organic and flaked stone points

Organic Points	Stone Points
Material limits morphology	More varied morphology possible
Considerable time to manufacture	Can be made relatively quickly
Cause less tissue damage	Cause great tissue damage, bleeding
More durable:	Less durable:
<ul style="list-style-type: none"> <li>• unaffected by cold weather</li> <li>• rarely damaged in transport</li> <li>• rarely break in use</li> </ul>	<ul style="list-style-type: none"> <li>• more brittle in cold weather</li> <li>• easily damaged in transport</li> <li>• invariably break on missed shot</li> <li>• frequently shatter when penetrating prey</li> </ul>
Easily repaired/resharpened	Difficult or impossible to repair
Less likely to be used with foreshaft	More often used with foreshaft
Reusable	Expendable

Table 8.2. Ethnographic situational use of organic and flaked stone points

Organic Points Used	Stone Points Used
On thrusting spears without foreshafts against herd animals	When hunting large game
Against large/dangerous animals without replacement weapons	When attacking dangerous solitary animals (bears)
On thrusting spears used in hand-to-hand fighting	On thrusting spears when danger to user is slight
On arrows used in cold weather	For killing enemies at a distance
On spears cast in heavy brush	

Ellis’s review of ethnographic data suggests that various factors including ambient temperature and prey type condition the selection and use of organic or flaked stone points. The primary factor underlying these situational decisions appears to be the cost or risk associated with weapon failure (Bamforth and Bleed 1997; Torrence 1989). When the potential cost is relatively low, stone points tend to be used. When the cost of failure is high, reliable weapons are called for (*sensu* Bleed 1987), and organic points are more likely to be employed.

### Costs and Benefits of Inset Points

Creating inset points involves manufacturing, using, and maintaining a complex toolkit in which we might find hard and soft hammers, pressure tools, holding devices, anvils, splitting wedges, grinders, scrapers, slotting tools (burins, gravers, saws), and mastic (Flenniken 1987; Tabarev 1997). Toolkits for *either* flaked stone or organic points contain fewer items.

The use of inset points in a weapons system is costly. It requires a large investment to learn how to produce microblades of a consistent width and thickness and how to do it quickly enough to meet demands in field conditions (Bamforth and Bleed 1997:132). Making microblades takes more time than producing bifaces from comparable amounts of raw material (Flenniken 1987). Making appropriate insets from microblade blanks and

installing them in the margins of slotted organic points requires still more time. It may also be costly to learn to create slots of consistent width and depth and time consuming to produce them.

Ellis (1997) does not cite ethnographic cases of inset point use. However, his review of ethnographic uses of organic points and flaked stone points suggests that the best design features of both are combined in inset points. Inset organic points can cause tissue damage and bleeding similar to that caused by stone points with less likelihood of breaking; they are both strong and lethal (Figure 8.1). Inset points can be used more than once, eliminating the need for frequent tip replacement and use of foreshafts. At the same time, inset points are highly maintainable, requiring only replacement of lost or broken insets and occasional tip resharpening. Batches of insets can be produced in anticipation of need (Bamforth and Bleed 1997:132; Kuhn 1994).

As we have suggested, however, the cost of producing inset points is much higher than that for weapons with organic or flaked stone tips. The payoff for the increased cost of inset weapons is their performance in situations in which the cost of failure is catastrophic and/or deadly: when they must be used multiple times without replacement, when the prey is a key resource that must be taken during a limited time, when the prey is a dangerous animal or a human enemy to be engaged at close quarters, or when the weapon is used in very cold environments.

### Relative Efficiency of Bifaces and Microblades in Production of Cutting Edge

After raw material is procured, the first step in preparation of virtually all varieties of wedge-shaped cores involves some degree of bifacial reduction (see Bleed, this volume). Thus, we must assume that all prehistoric knappers who made microblades from wedge-shaped cores could have produced bifaces to use as tools if they had chosen to do so. In some cases, bifaces used as tools and points do accompany microblades in lithic assemblages (Dyuktai Cave, Siberia; Uenodaira and Araya, Japan; Hutouliang and Pigeon Mountain Basin, China); in others, unifacially modified flakes (Afontova Gora-2, Siberia) and macroblades (Kokorevo-2, Siberia) serve the same functions as bifacial knives and points.

While this variability is no doubt multidimensional, we explore a few aspects of it by comparing the costs and benefits of producing bifaces and microblades. Our analysis makes use of experimental data (Table 8.3) provided by Flenniken (1987). To compare time and raw material consumption of the two techniques, Flenniken experimentally produced microblades from replicate Dyuktai bifacial cores, and, as well, made finished bifaces. As blanks to start the reduction process, he used large flakes of comparable size for both the wedge-shaped cores and bifaces. Flenniken (1987:122–132) concluded from his experiment that production of bifaces is the least economical use of toolstone because, while usable microblades (average 101 per core) comprised 41.6 percent of prepared core weight, finished bifaces comprised only 29.5 percent of blank weight. However, our analysis suggests this conclusion may be incorrect because Flenniken apparently did not calculate wastage of each technique as a proportion of the original weight of the raw material blank, nor did he include the final production step of microblade production.

Flenniken (1987) does not report the mean weights of the flake blanks used as the initial starting points of reduction. We are able to estimate, however, the weights of key products and by-products by using the mean weights of Stage 2 bifaces as a starting point and working back through the process using the proportions of products and debitage reported. Flenniken reports a mean weight of 219.1 gm for the Stage 2 biface “blanks” used to make microblade cores. We assume that when Flenniken refers to “blanks” for the biface trajectory, he also means Stage 2 bifaces. This assumption is important and reasonable given (1) the statement that the reduction process started in each case with flakes of comparable size and (2) that the reported starting weights

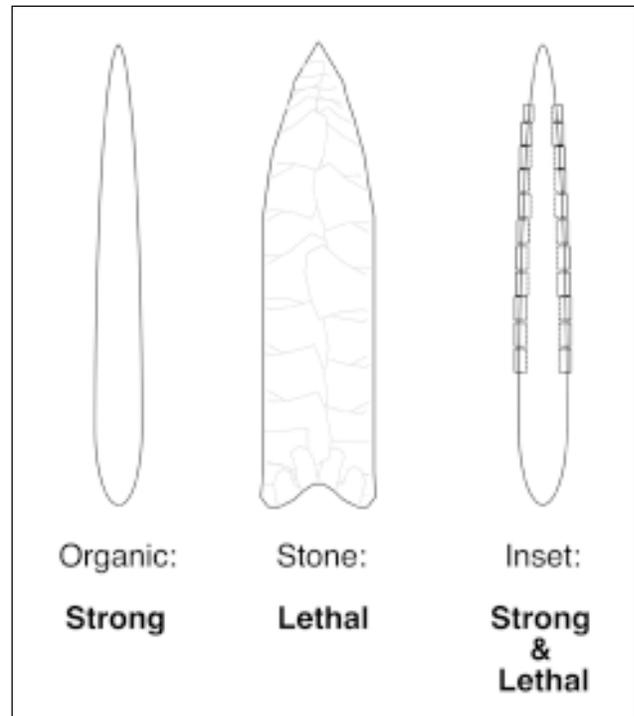


Figure 8.1. Organic, stone, and inset organic points compared.

for microblade cores (Stage 2 biface) and formal bifaces (“blank”) are equivalent. Comparisons based on these assumed equivalencies indicated that as much as 69.85 percent of the initial raw material is wasted in microblade core preparation, reduction, and maintenance; 30.15 percent of the initial raw material is converted into microblades. The production of completed bifaces uses 70.5 percent of the initial raw material; 29.5 percent of the initial blank weight is retained in the final biface.

This comparison suggests that there is *no* clear advantage in raw material economy between the two techniques. However, there are further potential costs and benefits associated with these technologies. Importantly, a handful of microblades is merely a bundle of stone splinters, not a finished tool. Insets, commonly made by snapping off both ends of the microblade, comprise about one-third to one-half of the intact microblade weight. Thus, 33 gm of snapped microblade insets from 66 gm of microblades per core in Flenniken’s experiment is only 15.06 percent of the initial blank weight, less than half the yield of finished bifaces. Flenniken also points out that microblades cost more in time to produce; he took 51 minutes on average to make about 100 microblades, or about twice the time per core (exclusive of heat treatment) used to make each biface. Thus, compared with microblade production, biface production appears to take less time and to make a more economical use of raw material.

At the same time, we are aware that bifaces and microblades may represent different technological modalities that are not directly comparable in terms of a general economic currency such as raw material weight. Recall that the focus of our discussion has been on the relative performance characteristics of inset and flaked stone points. Flaked stone points are so effectively lethal because of their *cutting edges*. If we assume that length of usable cutting edge is the currency to be maximized (Kuhn 1994), and production time is the cost to be minimized, we now have an equivalent basis for comparison. Flenniken’s experimental bifaces averaged about 15 cm in length, thus yielding a maximum of 30 cm of cutting edge (less if hafted) per biface. The mean microblade yield per core was 101. Assuming each microblade could provide an inset 2 cm long, the average core would provide 202 cm of cutting edge, nearly seven times that of the experimental biface for just twice the cost in time and the same cost in raw material.

Nevertheless, one might argue that the ability to resharpen a biface adds utility. While it is true that a biface used as a scraper or knife can be resharpened many times over a long use-life, a bifacial projectile point is likely to catastrophically fail after at most a few uses (Rondeau 1996). Most bifacial stone points probably could not be resharpened enough to match the 202 cm of inset cutting edge utility produced by microblade core reduction in the previous example. Additional utility may accrue from employing a biface as a tool prior to its service as a microblade core, as was sometimes the case in Japan (Bamforth and Bleed 1997) and China (Lu 1998),

and by using biface thinning flakes and ski spalls as tools or tool blanks. While such recycling can reduce raw material demands, and can provide additional cutting edge (cf. Kelly 1988; Kuhn 1994), it is not edge of the same uniform quality provided by insets, and it does not serve the same purpose as projectile point edges. Such cost and benefit analysis seems ripe for further exploration through experimental replication and modeling.

### Relative Efficiency of Boat-Shaped and Wedge-Shaped Microcores

Asian microblade cores are frequently divided into a large number of types (Chen and Wang 1989; Morlan 1976), though Seong (1998) has made a significant contribution by reducing these bewildering type lists to four basic variants. For the purposes of this chapter, we will distinguish between two basic approaches: boat-shaped cores made on split pebbles or thick flakes, and wedge-shaped cores made on bifacial blanks (Figure 8.2, A, B) (Kobayashi 1970).

Microblades can be produced from boat-shaped cores in a few steps (Morlan 1976). One primary advantage of boat-shaped cores is that they are usually produced from small, pebble-sized toolstone packages locally available in many geomorphic contexts. The use of a minimal number of technical steps in preparing boat-shaped cores appears to allow a large proportion of the pebble blanks to be turned into microblades (Seong 1998:272–274). Fewer steps in preparation may also reduce the risk of core failure since fewer things can go wrong. In con-

Table 8.3. Experimental microblade and biface production based on data in Flenniken (1987:122–123)

Reduction Stage	Mean Weight (g)	Previous Stage	% of Previous Stage
<i>Microblades</i>			
Initial flake	not given		
Stage 2 biface	219.1		
Prepared bifacial core (w/ski spall removed)	158.8	Stage 2 biface	72.48
Exhausted microblade core	33.4	prepared core	21.03
Prepared microblade core wt. minus exhausted core wt.	125.4		
Average of 101 usable microblades per core reduction	not given		
Microblades per reduction of prepared core (equal to 41.6% of prepared core wt.)	66.06	Stage 2 biface	30.15
Insets produced from microblades	33.0	Stage 2 biface	15.06
<i>Bifaces</i>			
Initial flake	not given		
Stage 2 biface (ca. the same as for microblade trajectory)	219.1		
Completed biface	64.6	Stage 2 biface	29.5

trast, bifacially prepared wedge-shaped cores require large toolstone packages, which may not be available locally. Preparation of a wedge-shaped core involves minimally the initial preparation of a biface, removing one margin (ski spall) to form the platform, adjusting the platform margins to fit the holding device, and then removing a crested blade to start the working face (cf. Figure 8.2, A; Bleed, this volume; Flenniken 1987; Tabarev 1997).

Although we presently lack supporting experimental data, we believe that the advantage of the wedge-shaped core over the boat-shaped core lies in greater uniformity of the microblades produced. Microblades from wedge-shaped cores should yield microblades with less variation in width and thickness, less ventral and lateral curvature, and more units with a trapezoidal cross

section—all qualities that enhance the efficiency of microblades as components of slotted organic armatures.

For example, consider a collection of microblades recovered from QG3, a Mesolithic archaeological site in Pigeon Mountain Basin, Ningxia, China (Elston et al. 1997; Madsen et al. 1998). These are divided into two classes: production microblades to be used as insets and maintenance microblades detached to maintain optimum core geometry and adjust core radius. The ratio of production to maintenance microblades in the QG3 sample suggests that for every production microblade, more than one maintenance microblade was removed. The former are wider and thinner, with more parallel margins and less ventral curvature, and some are retouched. Note in Table 8.4 that the thickness mean and standard deviation(s) are less for production microblades than for

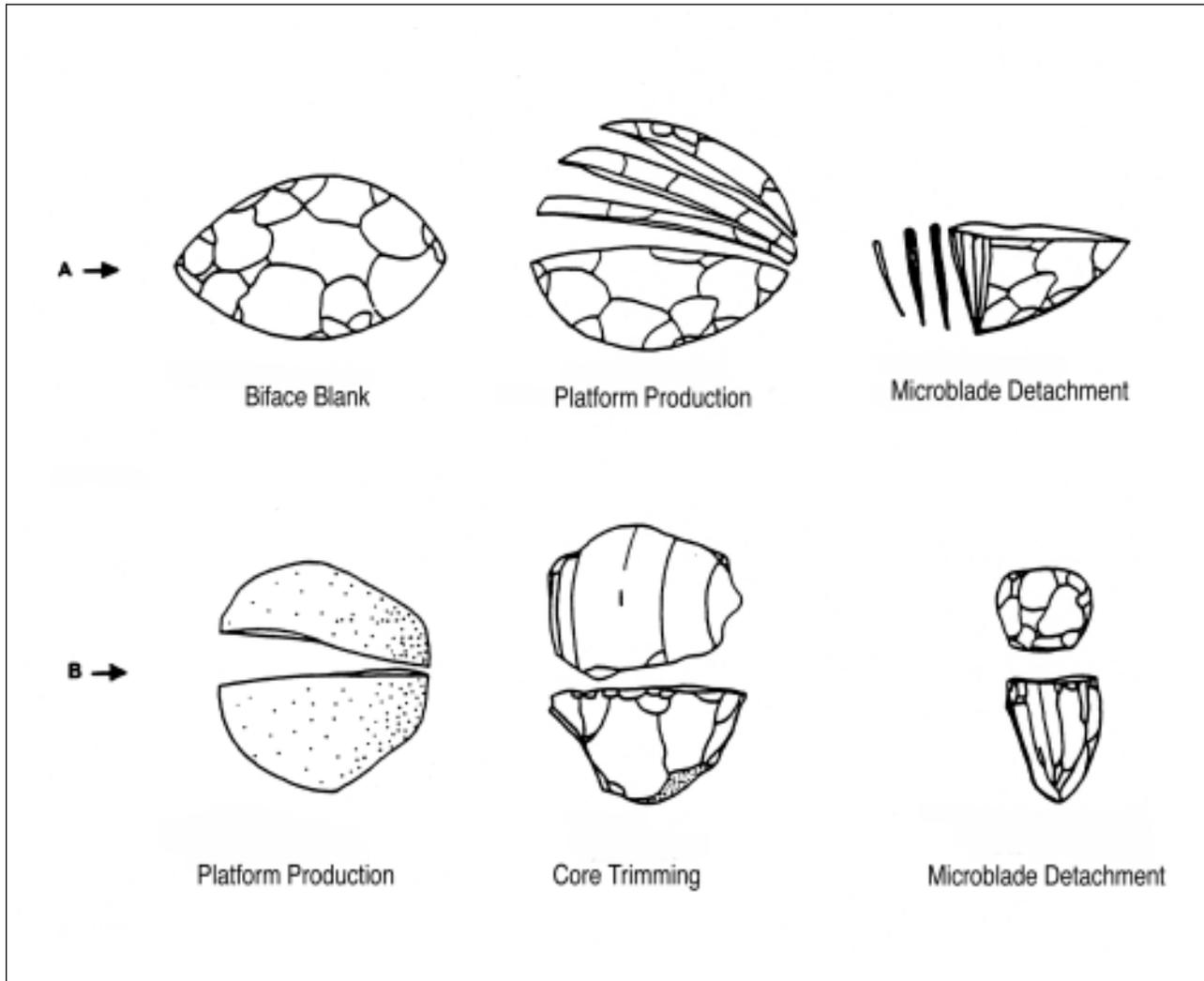


Figure 8.2. Asian microblade cores. A, Wedge-shaped made from biface blank; B, boat-shaped made on split-pebble blank (from Kobayashi 1970, used with permission, University of Wisconsin Press).

maintenance microblades from QG3. This suggests a concern of the QG3 knappers was to constrain production microblade thickness to a narrow, slot-fitting standard.

The manner in which wedge-shaped cores help constrain microblade variability is illustrated in a simplified model of core geometry (Figure 8.3) that demonstrates the relationships between three key variables: the radius of the core working face (from which microblades are detached) and the width and thickness of detached microblades.

Imagine that the working face of the core is a cylinder (Figure 8.3, a), which in plan view (looking down on the platform) approximates the arc of a circle with radius  $r$  (Figure 8.3, b). The width of a microblade detached from the core approximates a chord  $c$ , with microblade thickness  $x$ . The intersection of  $x$  and  $c$  forms a right angle.

By the Pythagorean theorem:

$$r^2 = (r-x)^2 + \left(\frac{c}{2}\right)^2 \tag{1}$$

Rearranging equation 1 for  $c$ :

$$c = 2\sqrt{2(rx) - x^2} \tag{2}$$

Core face maintenance is necessary on all microblade cores because microblade removal tends to increase  $r$  locally (Figure 8.3, c). Maintenance should be less efficient on cores with wide working faces where  $r$  can freely increase, and more efficient on wedge-shaped cores whose narrow working faces help prevent  $r$  from increasing beyond a certain value (Figure 8.3, d). The wedge-shaped core will require removal of less material (smaller maintenance microblades) for maintenance.

To illustrate the relationship between  $c$  and  $x$ , Figure 8.4 is a plot of values for microblade width  $c$  by equation 2, where thickness  $x$  is constant (using the QG3 production microblade mean of 1.56 mm) and  $r$  varies between 2 mm and 40 mm. As  $r$  increases, so does width  $c$ , but at a decelerating rate. Thus, when  $r$  is small (below about 10 mm) small adjustments to the core have a large effect on microblade width ( $c$ ).

Rearranging equation 1 for  $r$ :

$$r = \frac{1}{2} \left( \frac{x^2 + \frac{1}{4}c^2}{x} \right) \tag{3}$$

Production microblades from site QG3 have a mean width of 6.00 mm and mean thickness of 1.56 mm (Table 8.4). By equation 3, it appears that the QG3 knappers em-

Table 8.4. Width and thickness of production and maintenance microblades from site QG3, Ningxia, China

	n	Mean Width	$\sigma$	Mean Thickness	$\sigma$
Production	81	6.00	1.79	1.56	0.69
Maintenance	130	5.23	1.58	1.76	1.68

ployed microcores with a working face radius  $r$  of about 3.7 mm, somewhat larger than a BB shot. Since this value is much smaller than the width of any cores recovered from the site, we assume that the ancient knappers must have created local regions where the *effective* radius was small, by removal of maintenance blades and by otherwise relieving the platforms of production microblades before their detachment. On wide cylindrical cores (Figure 8.3, c), this process would have produced more variable results and wasted more material than on narrow wedge-shaped cores (Figure 8.3, d).

### Risk and Microblade Technology

The archaeological record suggests the relationship between boat-shaped and wedge-shaped cores is not developmental or evolutionary. In Japan, the first microcores to appear are boat-shaped, but these are later supplanted by wedge-shaped cores (Aikens and Higuchi 1982; Andrefsky 1987; Kobayashi 1970); however, in Korea, wedge-shaped cores appear first, followed by boat-shaped cores (Seong 1998). In China, boat-shaped cores are earliest, but remain in use when wedge-shaped cores appear (Chen 1984; Chen and Wang 1989; Lu 1998). In Siberia, the first microblades were made on miniaturized prismatic or conical blade cores; later, true microcores included both boat-shaped and wedge-shaped forms (Derev'anko 1998; Goebel 1995; Goebel et al. 2000; Goebel and Slobodin 2001; Hoffecker et al. 1993). In this light, variation in the proportions of boat-shaped to wedge-shaped cores in lithic assemblages appears to reflect a number of situational factors. In certain times and places, the need for uniformity is paramount; in other circumstances, it is not. Some of this variation is due to raw material availability (Seong 1998), but much of it may be a response to risk.

Winterhalder et al. (1999:302) define risk as “unpredictable variation in the outcome of a behavior,” with fitness or utility consequences. When such consequences are nonlinear, the behavior can be analyzed with one of a family of risk-sensitive models, including the Z-score model (Bettinger 1991; Stephens and Charnov 1982; Winterhalder et al. 1999). Risk-sensitive analysis requires

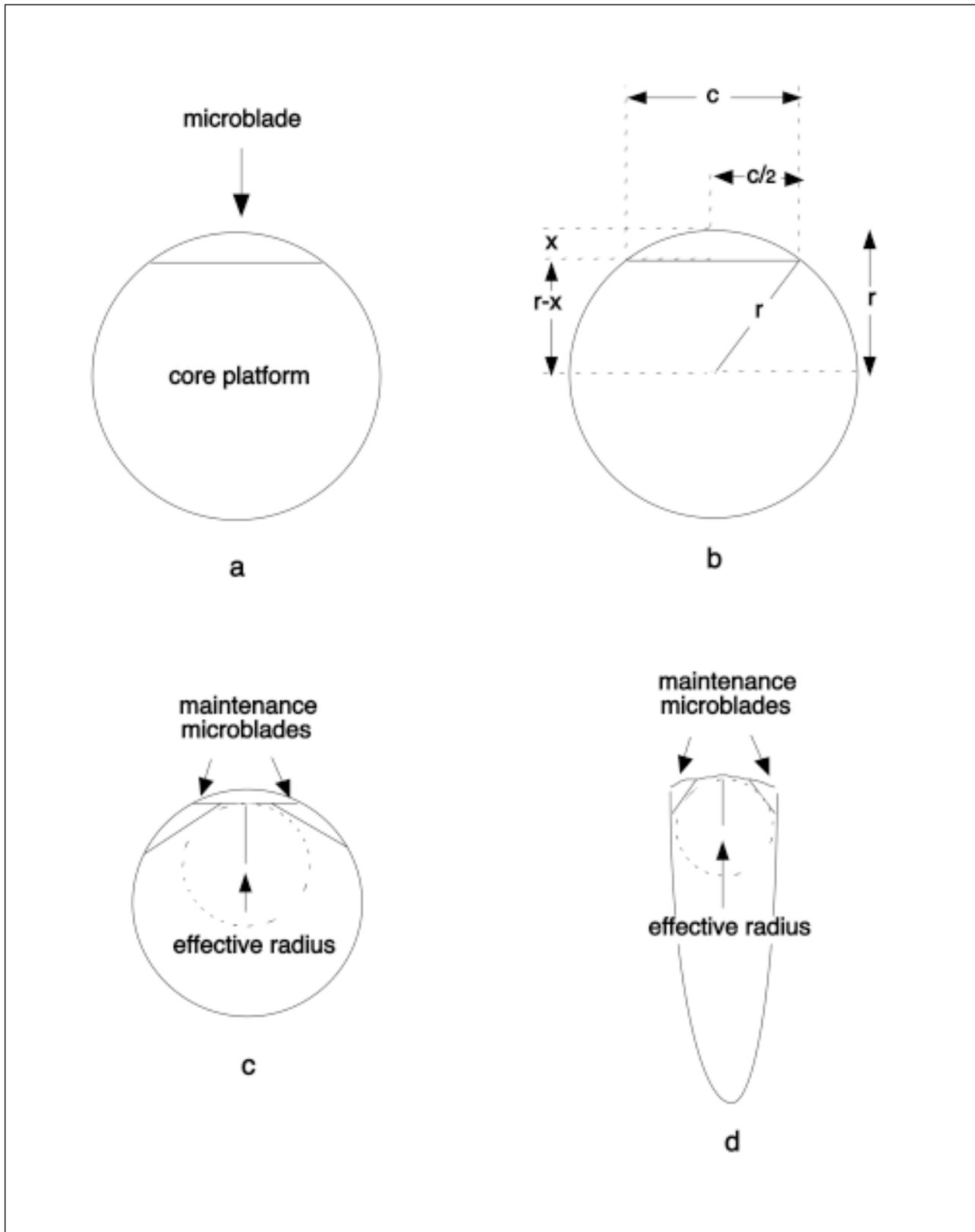


Figure 8.3. Simplified model of core geometry. a, Core platform and microblade; b, geometric relationships; c, reducing effective radius with maintenance microblades; d, small effective radius on wedge-shaped core.

the assignment or estimation of the probability outcomes for each behavior and specification of outcomes and their values as utility or fitness. Most studies of risk sensitivity have shown both animals and humans avoid risk; risk-prone behavior with regard to food selection is invariably a response to dire shortfall.

The Z-score model calculates the probability of a resource shortfall as the distance from the shortfall threshold ( $r_{min}$ ) to the mean ( $\mu$ ) and standard deviation ( $\sigma$ ) of the expected return:

$$Z = \frac{(r_{min} - \mu)}{\sigma} \tag{4}$$

When the mean expected return is below  $r_{min}$ , a more variable behavior (higher Z) will increase the probability of surpassing the shortfall threshold and consequently reduce overall risk. In Figure 8.5, for example, behaviors a and b share means below  $r_{min}$ , but the model predicts that behavior b (with its greater  $\sigma$ ) will be preferred. Conversely, when the mean expected return is above  $r_{min}$ , Z will be negative, and a less variable behavior (lower  $\sigma$ ) will be less risky. In Figure 8.5, where the means of behaviors c and d are both above  $r_{min}$ , behavior c, with its smaller Z, will be preferred over behavior d. Because points falling on a particular line have the same Z, a forager should be indifferent to choices among them (i.e., behaviors c and e in Figure 8.5).

In the case of microblade technology, it seems likely that wedge-shaped and boat-shaped cores each have a different probability distribution in yield of production microblades. While we cannot yet specify the probability outcomes, we strongly suspect that wedge-shaped cores reduce variability in microblade output. The Z-score model offers a generalized framework for predicting when precision and uniformity may be necessary in microblade production.

These relationships are modeled in Figure 8.6, where the vertical axis represents continuous values of possible returns; shortfall thresholds of hunting returns below which starvation becomes increasingly likely ( $r_{min}a-c$ ) are indicated by dashed horizontal lines; and means and standard deviations of microblade output from wedge-shaped cores (W) and boat-shaped cores (B) are represented by dots and lines. Here, behaviors W and B have the same mean ( $\mu$ ), but the standard deviation ( $\sigma$ ) of B is greater. For present purposes, let us assume that different technological behaviors influence the outcome ( $\mu$  and  $\sigma$ ) of hunting success. In situations in which expected returns are above the threshold, and the cost of failure is high (hunting for winter meat far from base camp), hunters can be expected to make choices that re-

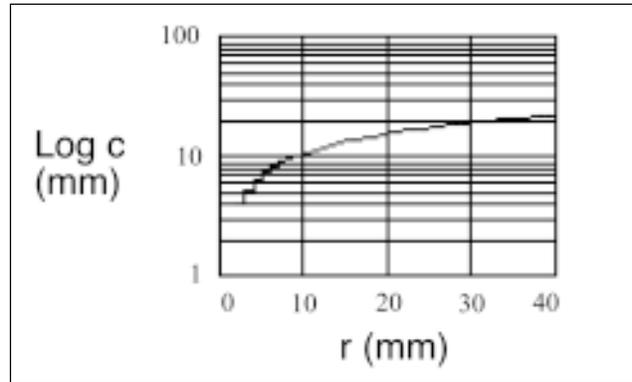


Figure 8.4. Step plot of core radius ( $r$ ) and log microblade width.

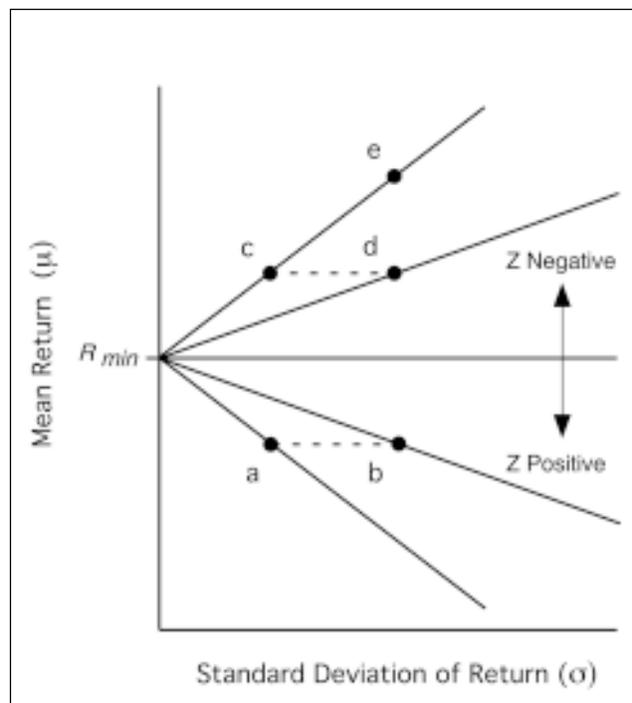


Figure 8.5. Isovalue map for risk-sensitive Z-score model (after Winterhalder et al. 1999:fig. 2).

duce behavioral variation around the expected mean. This situation is graphically represented in Figure 8.6 when the shortfall threshold is equal to  $r_{min}a$ , and the means of both W and B lie above it. Production from wedge-shaped cores (W) is the better choice, because there is a chance that output from boat-shaped cores (B) will fall below  $r_{min}a$ . In this situation, boat-shaped cores should rarely, if ever, be used. Variation and risk can be further reduced by making wedge-shaped cores part of the transported hunt toolkit, thus ensuring the availability of the highest-quality replacement parts. While hunters could manufacture batches of microblades before the hunting trip, their transport introduces the possibility of dulling

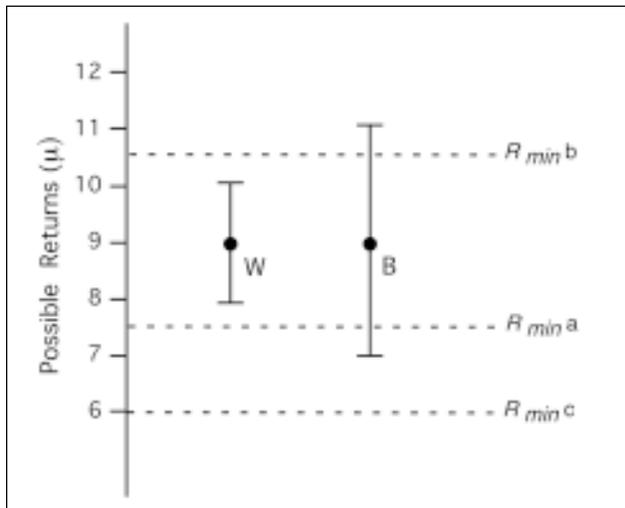


Figure 8.6. Choice model for microblade production using wedge-shaped cores (W) and boat-shaped cores (B) in relation to hypothetical production shortfall thresholds ( $r_{\min}a$ – $c$ ). Dots and vertical lines for W and B are means and standard deviations. For  $r_{\min}a$ , choice of W will lower risk of falling below threshold; for  $r_{\min}b$ , choice of B will increase the chance of meeting the threshold. For  $r_{\min}c$ , neither W nor B will increase risk of falling below the threshold; the choice between them is more likely to be made in consideration of factors other than risk.

and breakage (Ellis 1997:58). Furthermore, the transported supply may turn out to be insufficient to meet all the contingencies of the hunt. In many (but not all) situations, therefore, transporting cores will do more to reduce variance in return.

What if these same hunters find they need more microblades than can be produced from their supply of wedge-shaped cores? In Figure 8.6, this situation pertains when the shortfall threshold is equal to  $r_{\min}b$ . Both W and B share equal means that lie below  $r_{\min}b$ , but the model predicts that the hunters should try making microblades from whatever material is available, including boat-shaped cores on split pebbles (B). This tactic at least stands a chance of exceeding the threshold ( $r_{\min}b$ ). The proportion of usable microblades to waste matters relatively little in this context in which high variability in output can be tolerated with little cost.

Figure 8.6 also helps us to imagine situations in which the shortfall threshold ( $r_{\min}c$ ) is below the mean of either microblade production technique. In this case, foragers may be indifferent to whether boat-shaped or wedge-shaped cores are used from the standpoint of risk reduction, but other contingencies may apply. For example, if prey structure varies seasonally, production in anticipation of critical hunts could be less important in some seasons. Or perhaps certain classes of individuals

tend to use the technology with the more variable output, such that we might see boat-shaped cores used to train children in microblade production techniques or perhaps boat-shaped cores used by women to produce tools for their own needs around camp.

The point is not whether any of these scenarios truly reflect prehistoric behavior, but that risk-sensitivity models, including the Z-score model, help frame lithic variability differently, and more productively, than does a focus on typology. In principle, the implementation of the Z-score model in the study of microblade assemblage variability is straightforward. The model suggests that risk should condition variability in microblade dimensions, raw materials, core dimensions, and production technology. It should be possible to estimate the relative risk inherent in different prehistoric situations (cf. Bleed, this volume) and arrange them along an ordinal scale, perhaps represented at one end by time-limited hunts of large animals such as caribou, and on the other by summer occupation of residential bases. Testing such hypotheses requires metric measurements of microblades and microblade production debris from multiple assemblages of sufficient size and lack of bias. Unfortunately, assemblages from northern Asia meeting the above criteria are not yet abundant. Future studies will depend on consistent application of fine screening and attention to metric measurements in assemblage analyses.

### The Emergence of Microlithic Technology in Northern Asia

Although we argue that the use of inset points in Asia is contingent and situational, we are presently able to match their use only with the most general environmental parameters. Microlithic technology is strongly associated with latitude (Bamforth and Bleed 1997; Bettinger et al. 1994; Derev'anko 1998; Elston 2002; Goebel, this volume; Kuzmin and Orlova 1998; Kuzmin and Tankersley 1996; Lu 1998, 1999; Morlan 1970), occurring from about 33°N to above 70°N, and from far western China and Siberia to the Pacific coast, Sakhalin Island, and the islands of Japan. This northerly distribution suggests that Asian microlithic technology and inset weapons are in part a solution to problems of provisioning through long, harsh winters when resources are less abundant and more difficult to access, and when failure to procure sufficient resources has fatal consequences (Bamforth and Bleed 1997; Torrence 1983, 1989).

This hypothesis may be further supported by the timing of the appearance of microlithic technology summarized by Goebel (this volume). North Asian

hunter-gatherers may have started experimenting with microlithic technology during the last glacial maximum (LGM), although it did not become an important part of toolkits until post-LGM times, most likely between 17,000 to 18,000 B.P. Many of the skills and much of the knowledge required to initiate the production of microblades were inherent in the macroblade technologies of the Siberian early Upper Paleolithic, but not in China except for the brief incursion at Shuidonggou (Brantingham 1999; Madsen et al. 2001). The development of indirect percussion, or precision pressure flaking techniques using specialized indenters, may have allowed knappers to surpass a major threshold in workable toolstone package sizes. These innovations and the development of microlithic technologies in general were likely keyed to strategies for reducing foraging risk.

It is impossible at present to do more than present the above scenario as a hypothesis requiring further testing. The faunal record from China for this period is very poor. There is more faunal information from Siberia (Goebel, this volume) that implicates microblade use with reindeer hunting. However, the detailed faunal analyses needed to assess diet breadth, body part utility, prey population dynamics, or seasonality do not presently exist.

What is common over this region in the late Pleistocene is climate, which was cold, dry, and increasingly variable after the LGM. While mean annual temperatures gradually increased following the LGM, this did not make long winters any easier to bear for humans. Furthermore, warming caused changes in the distribution of prey animals as the “mammoth fauna” (Powers 1996) retreated northward and remaining species rearranged themselves. For example, in China large lakes reappeared in the deserts of the Ordos and Tengger (Madsen et al. 1998), but we suspect that if large game was attracted to these “oases,” hunting pressure would have soon reduced numbers of species and prey abundance. This may also have been the case in Siberia at this time for which Powers (1996) describes the environment as “hyperzonal”; that is, lacking the vegetation zones we see today, but divided into myriad small patches of steppe, forest, and tundra. While this helps account for the wide range of species present in some late Pleistocene archaeological sites, its likely effect on hunters would have been to increase mobility, since small “good patches” could be quickly depleted. If human populations were growing at the same time, this would have further stressed the dwindling faunal resource base and increased the variability in hunting returns. Microlithic technology can be viewed

as part of a strategy of intensifying large-game hunting to help cope with the increasing seasonal variance and unpredictability of key resources.

Large-game hunting was important through the Pleistocene/Holocene transition, and the use of inset points continued as well, suggesting that animals remained key resources. However, now shortages and high variation in prey availability were not just seasonal, but continually present. Beginning sometime after 14,000 B.P., technology was adopted allowing the efficient use of lower ranked resources such as seeds, signaled by the appearance of grinding tools and pottery in southern Siberia, Mongolia, and China (Elston et al. 1997; Fairservis 1993; Kuzmin et al. 1997; Lu 1999; Maringer 1950; Zhuschikhovskaya 1997). Where it could be practiced, Neolithic agriculture finally solved this set of subsistence problems, and microblades faded out of general use soon thereafter (Lu 1999). Microblades tended to persist only in the parts of northern Asia and in the New World where agriculture was late or unfeasible; where hunting to provision over winter in a patchy environment remained a risky, but key, subsistence strategy. Of course, as this volume makes abundantly clear, tactics designed to cope with risks of cold-weather large-game hunting do not explain microlithic technologies and composite armatures in other parts of the world where it was not cold and large animals were not hunted (i.e., southwest Asia, Australia). Nevertheless, foragers face other risks (time-limited critical resources, human enemies, and so on) that may be reduced using microliths and composite armatures.

## Conclusion

Our goal in this chapter was to illustrate the value of thinking about microlithic technology in terms of adaptive strategy and risk management, rather than in terms of origins and typology. We believe that this approach will help us comprehend the variable role played by microlithic technology in north Asian hunter-gatherer economies. Formal models of risk and utility (such as the Z-score model, transport cost models, toolstone procurement models, and tool utility models) in conjunction with experimental replication will illuminate lithic assemblage variation at local and regional scales (Elston and Zeanah 2002; Kuhn 1994; Metcalf and Barlow 1992; Zeanah et al. 1995). These models are, however, unlikely to generate fully testable hypotheses without much better faunal data than presently exist. Although most of the Siberian faunal assemblages remain to be analyzed using contemporary zooarchae-

ological methods, at least the collections exist. This is not the case for China where many fewer sites of the late Pleistocene are known and fewer still have even species lists. We hope that by demonstrating the utility of this kind of approach, more archaeologists will become interested in applying it.

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