



Coping with risk: Later stone age technological strategies at Blydefontein Rock Shelter, South Africa

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Abstract

I use Later Stone Age artifacts and faunal remains from Blydefontein Rock Shelter in the eastern Karoo, South Africa to investigate the interaction between risk and hunter–gatherer technological organization. Modifications in stone-tool repair and replacement are influenced by changes in past environments, resources, and the economic and settlement strategies of these Later Stone Age hunter–gatherers. The technological approaches range from time-minimization tactics to resource-maximization tactics. Time-minimization tactics favor the intense curation of extractive tools and the expedient use of maintenance tools, while resource-maximization tactics employ a more rapid replacement of extractive tools coupled with intense curation of maintenance tools. Time-minimization tactics occur with lower risk wetter conditions and the selection of larger animals for prey, while resource-maximization tactics correspond to higher risk conditions during drier periods and the more intensive exploitation of smaller animals. Efficient technologies were also employed for the rapid production of backed microlithic tools, but this does not appear to be in response to economic or environmental factors.

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Introduction

In the Karoo of South Africa, Later Stone Age (LSA) hunter–gatherers occupied Blydefontein Rock Shelter sporadically in the Late Pleistocene and throughout the Holocene (Fig. 1). Discarded stone tools, lithic manufacturing debris, bone refuse, and hearths scattered throughout the stratified rock shelter's deposits, as well as the occasional potsherd in the later components, represent the enduring record of their encampments. This study examines ways by which these hunter–gatherers organized their technological strategies, especially regarding the design, use and maintenance of their stone tools, and how these

hunter–gatherers manipulated these strategies to cope with changing conditions through time. Tactical shifts coincide with environmental changes and with oscillations in the faunal remains. The correspondence of technological indicators with the economic and paleoenvironmental records suggests that short-term fluctuations in food availability and economic risk influenced hunter–gatherer technological responses.

First, I will discuss the theoretical foundations of this paper in terms of risk and organization of technology among hunter–gatherers, then present the South African evidence for Later Stone Age technology, and finish with an analysis of the Blydefontein Rock Shelter data. The approach taken here uses optimal foraging theory (Bettinger, 1991; Smith and Winterhalder, 1992; Winterhalder, 2001) and especially those tenets

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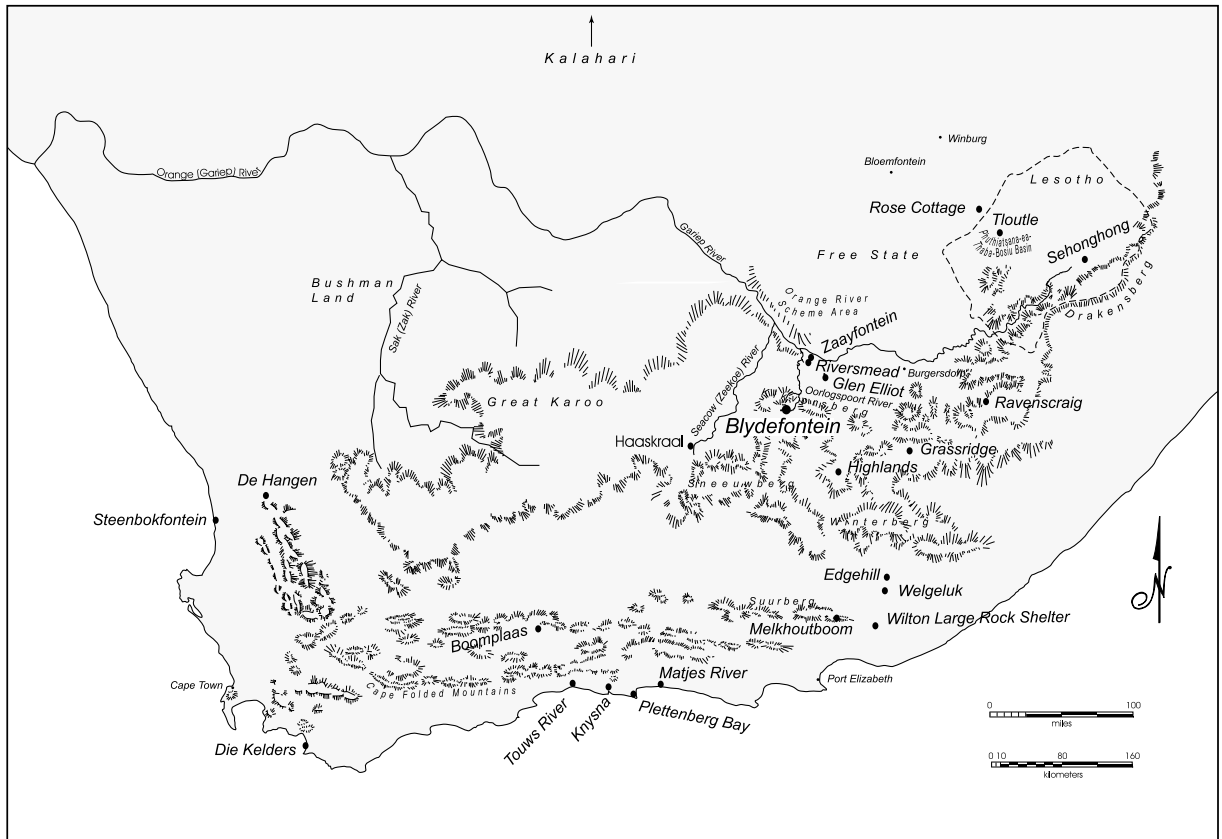


Fig. 1. Map of Southern Africa showing location of Blydefontein Rock Shelter, significant LSA sites, and landmarks.

concerned with risk management (Cashdan, 1990; Torrence, 1989, 2001; Wiessner, 1982). Risk has many different meanings, but in a general sense, scholars view risk either as a measure of unpredictable physical peril or uncertain economic returns. The following discussion only considers risk in terms of uncertain economic returns.

Economic risk and hunter–gatherer technology

Economic risk gauges resource availability in terms of abundance, diversity, and spatial and temporal distributions (Cashdan, 1990). Torrence (1989), who published one of the first and best argued cases illustrating the influence of risk on technological strategies, partitioned risk into two components: the probability of an economic shortfall (likelihood-of-loss) and the severity of an economic shortfall (cost-of-loss). In hunter–gatherer economies, the likelihood and severity of shortfalls are determined by a multitude of factors that include seasonal climatic patterns, unpredictable weather, prey density and their ecological relationships, and the specific hunting and gathering tactics that include mobility and technology, as well as the social strategies that influence access to food (Wilmsen and Durham, 1988). Most archaeologists view

risk solely in terms of likelihood-of-loss (cf. Jochim, 1976). However, as Torrence (1989), and Bamforth and Bleed (1997) persuasively argue, it is not only the frequency but also the severity of shortfalls, and thus the costs of overcoming these shortfalls that provide the most important limiting factors to human survival. Bamforth and Bleed (1997, p. 117) present a simple analogy that is worth repeating. The probability of falling off a tightrope is the same whether it is 1 or 100 ft. above the ground, but the costs of falling off the two tightropes differ dramatically.

Backup resources also diminish the cost-of-loss (Bamforth and Bleed, 1997). For example, hunter–gatherers in far northern latitudes often focus their seasonal economic pursuits on one or two resources with few, if any, available backup resources (Kelly, 1995). Risks are different in other areas such as Southern Africa where hunter–gatherers exploit a wider variety of resources if preferred food sources fail. This is not to say that areas like Southern Africa are not risky and that the potential for starvation was not a serious factor for prehistoric hunter–gatherers, but the structure of risk is different. In this paper, I assume that the timing and severity of shortfalls are the two harshest “selectional forces” that influence technology among hunters–gatherers.

Wiessner (1977, 1982) identifies four generalized strategies used by hunter–gatherers to cope with risk: (1) prevention-of-loss, (2) transfer-of-loss, (3) food storage, and (4) storage through social obligations. Bamforth and Bleed (1997) argue that archaeologists have spent too much effort investigating prevention-of-loss strategies, and other coping strategies should be our focus. Transfer-of-loss (sharing within a single group) and storage through social obligations (sharing between groups using reciprocal exchange systems such as hxaro) do not necessarily require technological devices (Wiessner, 1982), and these can be difficult to monitor with archaeological evidence.

Food storage often does involve technological strategies (Testart, 1982; Wiessner, 1982). For example, closer to the South African southern coast, Holocene sites such as Melkhoutboom and Boomplaas have storage pits with preserved seeds and corms (H.J. Deacon, 1976, 1979; Mitchell, 2002, pp. 175–176, 178), but hunter–gatherers in the Interior Plateau near Blydefontein never relied on storage intensively enough to develop elaborate technological devices. Many other hunter–gatherer societies follow a similar pattern. Consequently, this paper returns to prevention-of-loss strategies, especially those that influence hunter–gatherer technologies, as a valid topic for analysis.

While risk is difficult to monitor with ethnographic or archaeological data, a few attempts to document risk have been made over the last 20 or so years (Ambrose and Lorenz, 1990; Dyson-Hudson and Smith, 1978). One limitation is that very few modern hunter–gatherer studies report environmental information in great enough detail from which risk can be assessed, but see Wilmsen and Durham (1988) and Kent (1996) for notable exceptions. Another problem is that economic failure is almost never visible in the archaeological record and rarely recorded in ethnographic studies.

Marean (1997) presents one approach with his analysis of hunter–gatherer animal and plant exploitation in grasslands. This study shows that resource diversity and richness in tropical, temperate, and cold grasslands differ, and these patterns correspond to variations in climate. Although Marean (1997) did not relate these patterns formally to economic risk, it is clear that risk profiles for grassland biomes differ due to the seasonal severity of food shortfalls. In general, these examples are instructive for considering risk in the Blydefontein case.

Out of necessity, I use proxy estimates of risk based on detailed paleoenvironmental reconstructions. The data for these reconstructions come from geological sites with pollen, diatoms, molluscan fauna, stable isotopes, and hyrax (colloq.: dassie) dung middens with pollen, as well as from Blydefontein Rock Shelter with fauna, microfauna, and stable isotopes on ostrich eggshell (Avery, 1988; Bousman, 1991; Bousman et al., 1988; Bousman and Scott, 1994; Scott and Bousman, 1990; Scott et al., 2005).

Using paleoenvironmental data as a proxy measure of risk can lead to erroneous assessments. Minc and Smith (1989) provide an example of potential pitfalls. Using tree-ring records, they reconstruct resource fluctuations for neighboring inland and coastal areas in Northern Alaska during the historic period, and show that risk profiles in these two adjacent areas vary inversely with climatic conditions. Dry, warm conditions allow greater caribou calf survival in winter and increase productivity of caribou hunting for inland groups, while the same conditions decrease the hunting success of bowhead whale and ringed seal hunting at the coast due to the early breakup of sea ice. This inverse correlation with climate shows that simple equations with proxy evidence can be misleading. Care must be taken, but reasonable measures can be made with an understanding of local paleoecology.

Organization of technology

Archaeologists have introduced a series of concepts used in the study of technological organization (see Bousman, 1993 for more detailed summary). Binford and Binford (1966) distinguish between *extractive* and *maintenance* tasks and suggest that technology was designed to address the needs of these two distinct types of tasks. We can then classify tools as to their role in these primary functions as either extractive or maintenance tools. Extractive tools are those used to obtain food and maintenance tools are those used to manufacture or repair other technological devices.

Later, Binford (1973) introduced the concept of design goals and made a contrast between *expedient* and *curated* tools. Expedient tools are those manufactured, used and discarded instantly (Gould, 1980), while curated tools are kept for longer periods of time. A few years later Bleed (1986) contributed to this debate by introducing two important tool design concepts. These are *reliability* and *maintainability*; both would fit within Binford's curated tool class.

Reliable tools are designed to work when needed. In order to accomplish this goal they are often over-designed and complex. An example of a reliable tool is the Angm-aksilik toggle-headed harpoon with floats and throwing board (Oswalt, 1976, p. 99). Alternatively, hunter–gatherers design maintainable tools to be easily fixed or repaired. Aché (Guayaki) arrows with long wooden points that are often resharpened while hunters are hunting are good examples of maintainable tools (Clastres, 1972, pp. 146–147). Within the design of any single tool, these design goals are not necessarily exclusive.

Fig. 2 illustrates a graphic depiction of the balance between these three design goals (expediency, reliability, and maintainability) for two hypothetical tools, and furthermore these can be viewed independently by their primary tasks: extractive or maintenance. The balance

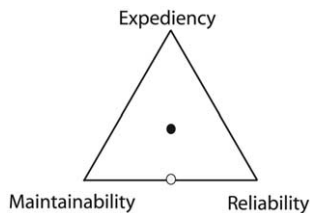


Fig. 2. Hypothetical tri-polar graph illustrating mix between reliability, maintainability, and expediency tool design goals. Black circle represents equal mix of all three goals, open circle represents an equal mix between reliability and maintainability.

between design goals for a single tool can change through time as conditions change (Bousman, 1993).

Technology incurs costs (handling costs) in terms of design, raw material procurement, manufacture, use, repair, and rates of discard, but it also offers distinct benefits (Bousman, 1993; Nelson, 1991; Torrence, 1983, 1989). I fully agree with Torrence (1989) that risk acts as a selective force to structure technological strategies, and coping with economic risks through prevention-of-loss strategies is one of the most important benefits of technology. Bamforth and Bleed (1997, p. 117) state that the problems caused by probability and cost components of risk should have different technological solutions, but most archaeological applications have not understood the affects of risk, and they tended to look only at the probability component.

One aspect of weapon design (*sensu* Oswalt, 1976) that Torrence (1989) and later Bamforth and Bleed (1997) assign to the cost-of-failure is tool *reliability*. Tool reliability is critical in situations where the cost-of-failure is high because tools must work in these situations. Alternatively, in situations where cost-of-failure is low, even if the probability-of-failure is high, the need for tool reliability is not as demanding.

Torrence (1989) also proposed that the frequency of shortfalls (likelihood-of-loss) determines the need for tool *maintainability*. Maintainable tools are designed for easy repair (Bleed, 1986). It seems reasonable to suggest that in situations where the costs of risk are lower, the manufacturing and maintenance costs of extractive tools may have a greater role in determining technological strategies. This could result in flexible extractive tools that are capable of procuring multiple resources, as well as technological strategies that offer reduced costs in terms of procurement, manufacture, and repair efforts.

If the above relationships are correct, then resource-maximization tactics might be favored in situations where the cost-of-failure is high and time-minimization tactics stressed in conditions when the cost-of-failure is low (Bousman, 1993). Nevertheless, as Bamforth and Bleed (1997, pp. 123–125) point out, because of local conditions, the ability to bear the attendant technological

costs may not be the same for all groups and this could also influence technological strategies.

Technology and hunter–gatherer economic strategies

In current models of technological organization, it is often argued that greater curation of lithic artifacts and more efficient technologies should be practiced by hunter–gatherer groups with low residential mobility and high logistic exploitation strategies (Andrefsky, 1994; Bamforth, 1986, 1991; Bamforth and Bleed, 1997; Binford, 1973, 1977, 1979, 1980; Bleed, 1986; Carr, 1994; Kelly, 1988, 1995; Mitchell, 2000, 2002; Nelson, 1991; Parry and Kelly, 1987; Shott, 1986, 1989; Torrence, 1983, 1989; although see Fitzhugh, 2001 and Tomka, 2001 for alternative views). It is well known that Binford (1980) identified groups with low residential mobility and high logistic mobility as collectors because they collect food in bulk and transported it back to residential groups. Expedient tool use and less efficient technologies have often been associated with exploitation strategies that emphasize greater residential mobility which move people to food. Binford (1980) identified these hunter–gatherers as foragers.

If we inspect the ethnographic record of hunter–gatherer technological strategies and current models for technological design and organization, the above model does not explain a number of observable behaviors. Unfortunately, anthropologists have studied very few hunter–gatherer groups in enough detail to provide useful information, but technological evidence is available for a Kalahari Bushmen group known as the !Kung (Lee, 1979), who call themselves the Ju/hoansi, and the Alaskan Ingalik (Osgood, 1940). The !Kung are characterized by high residential mobility, and the Ingalik employ low residential mobility linked with logistical tactics.

In Fig. 3 we see that the !Kung spend only a fraction of their time making tools, but get a great deal of use-life from these tools, while the Ingalik spend a great deal of

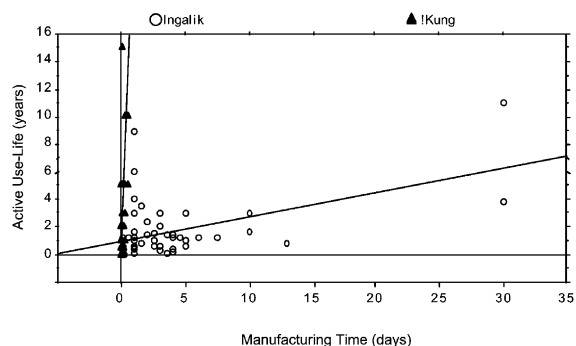


Fig. 3. Linear regressions between manufacturing time and use-life for Dobe !Kung and Ingalik tools (data from Lee, 1979; Osgood, 1940).

time manufacturing their tools given the amount of use-life they obtain from their tools. Shott (1989) originally looked at these groups, but the major difference between our analyses is that I subtracted the amount of time that a tool was cached from its use-life estimations (Bousman, 1993). This transforms the Ingalik pattern into a linear relationship between manufacturing time and use-life. It is significant that both groups use tools expediently and both curate tools. Therefore, models that propose that foragers use tools expediently and collectors curate tools are over simplifications, and are not supported by these data.

By separating the ethnographic tool assemblages into those used primarily for *extractive* tasks such as hunting or plant food collecting, and those tools used essentially for *maintenance* tasks such as hide preparation or making other tools (Binford and Binford, 1966), we can see a distinctive difference in the average tool use-lives among hunter–gatherers that emphasize residential or logistic mobility (Table 1). For this comparison, I was able to add one additional group, the Ngatatjara, a group from Australia with high residential mobility typical of foragers (Gould, 1980). In both cases, foragers obtain more use-life from their extractive tools than from their maintenance tools, while the logistically organized Ingalik get more use-life from their maintenance tools but keep their extractive tools for much shorter periods (*M/E* Ratio in Table 1). The *M/E* ratio is not as robust for the !Kung, but they use modern western materials with greater durability such as iron for arrow points, while the two other groups used available local materials of non-western origin. In the last few hundred years of their existence terminal LSA archers in some portions of Southern Africa also used iron from Bantu groups for projectile point tips (Sampson, 1967a).

As discussed above, Binford (1973) and Bleed (1986) have introduced three tool-design goals used by hunter–gatherers: expediency, reliability, and maintainability. These three strategies offer different costs and benefits. I believe that the selection of one technological strategy

over another is strongly conditioned by economic risk (Bamforth and Bleed, 1997; Bousman, 1993; Torrence, 1989, 2001), functional requirements (Tomka, 2001), and manufacture/maintenance patterns (see below).

Fig. 4 illustrates hypothetical cost and benefit relationships for each design goal. Expediency provides low manufacturing costs but offers low tool utility, because tools are not resharpened or repaired. They are discarded when exhausted, broken, the task is complete, or the work session is concluded. Maintainability involves moderate tool manufacturing costs, offers renewable utility by resharpening or repair, and tools are discarded when exhausted or broken. Reliability provides high tool utility, but with attendant higher costs due to over-design. Reliable tools could also incur higher costs if discarded early before exhaustion. A fourth technological strategy not shown on the graphs, that of an efficient technology, can be embedded within any of the above three tool-design goals, and its implementation cuts costs by reducing manufacture time. I could find no good ethnographic examples that illustrate shifts between efficient and inefficient strategies in Southern Africa, although North American archaeologist have argued that Folsom hunter–gatherers changed their fluting tactics to less wasteful methods in those situations where raw materials are scarce (Amick, 1995; Hofman, 1992).

These ethnographic patterns suggest that hunter–gatherers may employ at least two distinct strategies toward tool curation and tool maintenance. One strategy, favored by groups with high residential mobility, employs the extensive repair of extractive tools but relies on an expedient strategy for maintenance tools. The other strategy, perhaps more common among groups with logistical mobility, produces reliable extractive tools that are replaced rather than repaired, but uses maintenance tools that are repaired until exhausted and their utility fully depleted.

Kuhn (1989) suggests the replace-before-failure strategy for extractive tools is a response to high risks during food acquisition by collectors. Torrence (1989, 2001), and Bamforth and Bleed (1997) suggest that hunter–gatherers use over-designed, reliable extractive tools in those situations where failure-to-procure *costs* are high (i.e., the high tightrope), rather than those situations where the failure-to-procure *frequencies* are high but *costs* are low. Torrence (1989) also argues that when failure-to-procure frequencies are high, then it appears that extractive tools are repaired and used until exhausted, and thus intensively curated. These choices could be conditioned by the costs of obtaining raw materials, but economic risk is probably the more severe selectional factor.

Most archaeologists ignore maintenance-tool strategies or simply fail to distinguish between maintenance and extractive tools in organizational models. It seems reasonable to suggest that the costs and benefits of

Table 1
Extractive and maintenance tool mean use-life (years) for foragers (!Kung and Ngatatjara) and collectors (Ingalik)

	Maintenance tool use-life	Extractive tool use-life	<i>M/E</i> ratio
Foragers			
(!Kung)	3.3 ± 2.5 (n = 18)	4.2 ± 3.2 (n = 7)	0.79
(Ngatatjara)	0.04 ± 0 (n = 3)	2.4 ± 3.4 (n = 7)	0.02
Collectors			
(Ingalik)	1.7 ± 2.0 (n = 30)	1.4 ± 0.3 (n = 3)	1.21

M/E ratio equals maintenance tool use-life/extractive tool use-life (data from Gould, 1980; Lee, 1979; Osgood, 1940).

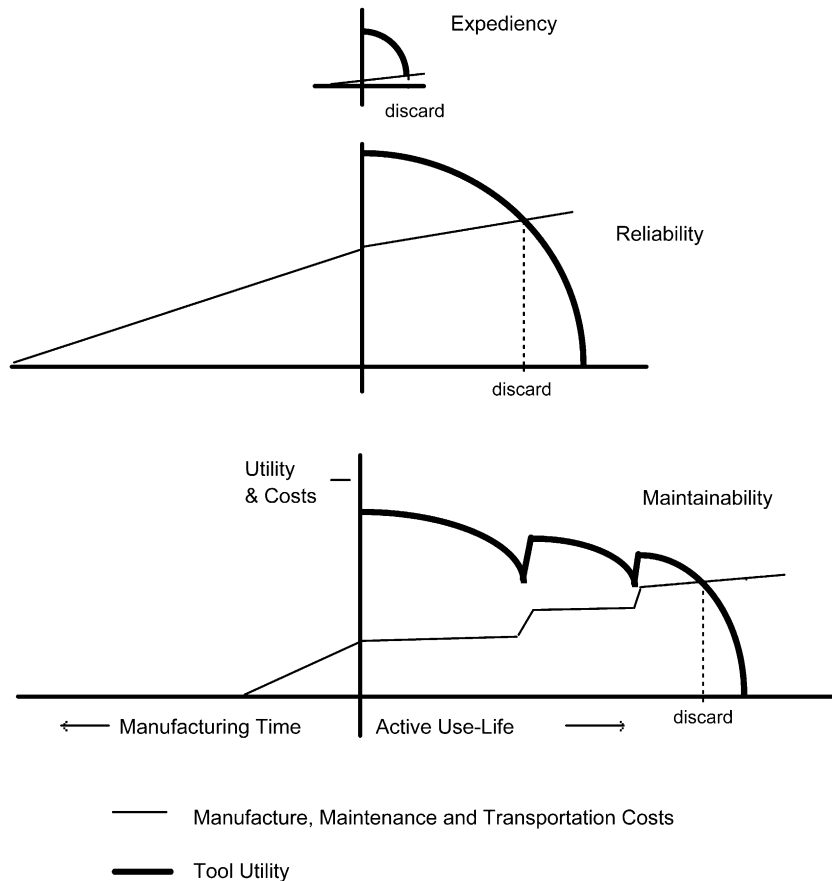


Fig. 4. Graph illustrating the relative costs and benefits (utility) of expedient, reliable, and maintainable tools.

maintenance tools differ dramatically from those of extractive tools as they are used in very different settings and for different purposes. Another possible factor that may influence maintenance-tool strategies is hunter-gatherer manufacture and repair work patterns. Below I suggest that differences in work strategies favor differences in the approach used toward the repair and curation of maintenance tools.

Hunter-gatherers who employ high logistic mobility use dedicated blocks of time, known as *gearing-up sessions*, for the manufacture and repair of tools and equipment (Damas, 1972). They schedule gearing-up sessions during periods when subsistence activities are unproductive (Oberg, 1973). During gearing-up sessions they depend heavily on stored foods (Binford, 1980), and they need to produce a large number and variety of technological devices in a limited period (Osgood, 1940). Often the manufactured devices are complex or reliable in Bleed's (1986) terminology. Because items are manufactured and repaired in quantity, many tasks are repetitive even though a variety of tools is constructed. As Hayden and Gargett (1988) have argued this type of

situation tends to favor specialized maintenance tools, and I would suggest much more intensive repair of maintenance tools. It would appear then, that groups with high logistic mobility and who exploit food in bulk, and make and repair tools in gearing-up sessions, attempt to get as much utility from their maintenance tools as possible. The utility of maintenance tools is renewed and sustained by repairing these tools until they are no longer usable or repairable.

Alternatively, foragers work on their tools in sporadic but quasi-continuous fashion throughout the year. Silberbauer (1981) called these work patterns *make-and-mend sessions*. These foragers, with frequent residential camp moves, may not be in the same location for each work session. They may not need to curate maintenance tools between each make-and-mend session especially if raw material is readily available, they move camps between make-and-mend sessions, or the cost of tool replacement is low. Yellen (1977, pp. 76–77) describes such a situation among the !Kung in the Kalahari. Hunter-gatherers with high residential mobility do not use maintenance tools as intensively nor for as long of a

Table 2
Ethnographic model of tool design and curation duration among foragers and collectors

	Foragers	Collectors
Extractive tools	Maintainable-long use	Reliable-short use
Maintenance tools	Expedient-very short use	Maintainable-long use

Categories represent modes and variations between modes should be viewed as continuous variables with unknown distributions.

period as collectors. The differences in the work patterns that foragers and collectors use for manufacturing and repairing tools could directly influence maintenance-tool curation and use. Recently, Tomka (2001) has made a similar argument although he suggests it is mostly the “processing requirements” that condition the degree of tool standardization and formality, but overall this is an issue little appreciated in the organization of technology literature.

This paper presents an ethnographic model of technological use, based on the above ethnographic patterns and arguments (Table 2). The patterns are easiest described as modes, but differences should be viewed as a pattern of continuous variation. Below I test this ethnographic model with the LSA data from Blydefontein Rock Shelter in the eastern Karoo of South Africa. I propose that these Later Stone Age hunter-gatherers designed and used their technological devices in a manner that was sensitive to fluctuations in the availability of resources and these patterns strongly influence the archaeological record in this region. In this analysis, I have attempted to integrate the concepts developed by optimal foraging and the organization-of-technology theorists, but much still remains to be done.

Setting

Blydefontein Rock Shelter is in a grassveld community near the eastern boundary of the semi-desert Karoo (Rutherford and Westfall, 1986). It is in a treeless and grassy, gently rolling basin perched in the upper reaches of the Oorlogspoort River drainage in the Kikvorsberg Range (see Fig. 1). Acocks (1975) classified the vegetation as Karroid *Merxmuellera* Mountain Veld. This is a grassveld community with a mixture of C₃ and C₄ grasses that today inhabits the higher elevations of mountains such as the Kikvorsberg and Sneeuwberg (Vogel et al., 1978). Dwarf C₃ bushes (colloq.: bossies) dominate the adjacent False Upper Karoo communities in the lower elevations of the Oorlogspoort basin and neighboring Zeekoe River valley (Acocks, 1975). At least from the Late Pleistocene and throughout the Holocene, paleoenvironmental studies demonstrate that vegetation

in Blydefontein Basin and surrounding areas fluctuated between grassveld and Karoo veld (Bousman et al., 1988; Bousman and Scott, 1994; Coetzee, 1967; Holmes, 2001; Holmes et al., 2003; Holmes and Marker, 1995; Partridge and Dalbey, 1986; Scott and Bousman, 1990; Scott and Cooremans, 1990; Scott et al., 2005; Thomas et al., 2002). It is reasonable to infer that these changes were due to variations in past climates (Bousman, 1991).

The regional archaeological sequence

Like many LSA sites in southern Africa (Carter et al., 1988; Deacon, 1976, 1978, 1984; Inskip, 1987; Mitchell, 2002; Opperman, 1987; Parkington, 1977; Sampson, 1974; Wadley, 1987, 1989, 1991, 1993), the archaeological sequence in Blydefontein Shelter contains a repeating sequence of technological shifts between microlithic and macrolithic assemblages. The cultural sequence at Blydefontein consists of Robberg, Lockshoek, Interior Wilton, and Smithfield components. The great majority of formal tools in the Blydefontein sequence consists of end scrapers and backed microliths.

Robberg assemblages are characterized by abundant bladelets, rare microlithic backed tools, and a few unifacial scrapers (Deacon, 1976, 1978, 1984; Mitchell, 1988, 1995, 2002; Wadley, 1993, 1996). In Southern Africa, most Robberg assemblages date to the Late Pleistocene (22,000–12,000 BP; all dates presented in radiocarbon years BP) at sites such as Melkhoutboom, Nelsons Bay Cave, Sehonghong, Heuningneskrans, and Byneskranskop (Beaumont, 1981; Carter et al., 1988; Deacon, 1976, 1978; Deacon and Deacon, 1999; Mitchell, 1988, 1995, 2002; Schweitzer and Wilson, 1982; Wadley, 1993), but in Layer LB at Rose Cottage Cave an assay of 9560 ± 70 BP (Pta-7275) was obtained recently by Wadley (1997) on a terminal Robberg assemblage suggesting a longer span. This extended temporal span needs to be supported by additional dates.

The Oakhurst Complex is generally later than the Robberg in most of Southern Africa, and it is easily distinguished by the presence of large scraping tools and a complete lack of microlith production (Deacon, 1978, 1984; Mitchell, 2002; Sampson, 1974). Lockshoek is the regional variant of the Oakhurst Complex in the eastern Karoo surrounding Blydefontein (Sampson, 1974). North West Province and Coastal Oakhurst assemblages have abundant bone tools and some probably were used as projectile tips (Deacon, 1976, 1984; Mitchell, 1997; Wadley, 1989). Oakhurst complex sites occur between 12,000–8000 BP (Deacon, 1984; Deacon and Deacon, 1999; Humphreys and Thackeray, 1983; Mitchell, 1997, 2002; Parkington, 1984; Sampson, 1974; Wadley, 1993).

Dating to the Holocene, Wilton components contain abundant microlithic tools that range in shape from crescents (segments) to straight-backed bladelets, and small thumbnail scrapers (Deacon, 1984; Mitchell, 1997, 2002; Sampson, 1974). Based on his Orange River

Scheme research, Sampson (1974) divided the Interior Wilton into Early, Classic, Developed, and Ceramic phases. Only one possible Early Wilton assemblage has been excavated in a well-stratified and dated context at Tloutle Rock Shelter in the Phuthiatsana-ea-Thaba-Bosiu Basin of western Lesotho near Maseru (Mitchell, 1993). In Layer CSL-LR at Tloutle Rock Shelter, an assemblage with microliths and large scrapers with steep lateral retouch was associated with a 7230 ± 80 BP (Pta-5171) radiocarbon date. This is an early age for Wilton and it is possible that it represents a transition between the Oakhurst Complex and Wilton Complex.

At Melkhoutboom in the Suurberg, Edgehill south of the Winterberg, Ravenscraig, and Grassridge the Drakensberg, Rose Cottage Cave in the Caledon River Valley, and Tloutle Rock Shelter in Lesotho (see Fig. 1) abundant Classic Wilton assemblages span the period between 7000 and 4000 BP (Deacon, 1976; Deacon and Deacon, 1999; Hall, 1990; Hall and Binneman, 1985; Mitchell, 1993, 2002; Opperman, 1987; Wadley, 1997). Classic Wilton assemblages contain small end scrapers and crescents (segments) microlithic tools. Only a few Classic Wilton sites were found in the nearby Zeekoe River Valley survey (Sampson, 1985), and Sampson (1967b) excavated only one good Classic Wilton assemblage at Zaayfontein in the Orange River Scheme area.

Developed Wilton assemblages are very common in the region surrounding Blydefontein and excavated at sites such as Highlands, Zaayfontein, and Riversmead shelters (Deacon, 1976; Sampson, 1967b, 1972, 1974; Sampson and Sampson, 1967). These assemblages contain straight-backed bladelets and slightly longer end scrapers. At the end of the Developed Wilton span, ceramics are found in sites, although there is little change in the stone tools.

The Smithfield Industry contains large end scrapers, bone points, and a very few microliths (Goodwin and van Riet Lowe, 1929; Close and Sampson, 1998a,b; Sampson, 1974). Excavations by Sampson and others (1989) show that Smithfield assemblages date to the last 1000 years and these were the historic Bushmen encountered by early explorers and trekboers in the 1700s (see also Bollong and Sampson, 1996; Bollong et al., 1993). In the southern Zeekoe Valley (Sadr and Sampson, 1999; Sampson, 1985, 1988, 1996; Sampson et al., 1989; Sampson and Sadr, 1999; Sampson and Vogel, 1995, 1996) the presence of Khoe ceramics and stone circular corrals (colloq.: kraals) demonstrates a dense occupation by herders 40–50 km southwest from Blydefontein.

Excavation, sequence, and stratigraphy at Blydefontein Shelter

Blydefontein is a large rock shelter (Fig. 5), at least in comparison to others nearby, carved into a sandstone



Fig. 5. Photograph of Blydefontein Rock Shelter and Blydefontein Stream terrace deposits.

cliff face by a small tributary stream of the Oorlogspoort River (Bousman, 1991; Sampson, 1970). The shelter's sediments, consisting of alluvium, roof fall, and anthropogenic deposits, sit slightly higher than the Blydefontein Stream terrace in front of the shelter, and interfinger with these terrace deposits. Geological exposures of infilled ponds, buried soils, and infilled stream channels in the Blydefontein Stream and Meerkat Stream terraces and stratified dassie dung middens in Oppermanskop and Meerkat rock shelters have produced most of the Late Pleistocene and Holocene paleoenvironmental information (Bousman et al., 1988; Bousman and Scott, 1994; Scott and Bousman, 1990; Scott et al., 2005). However, we obtained a valuable stable isotope sequence on ostrich eggshell from the Blydefontein Shelter excavation.

I excavated the deposits in 25×25 cm spits using a combination of natural layers and thin arbitrary levels. I also excavated the bioturbated deposits (burrows, etc.) separately and excluded the artifacts found in these deposits from the analysis. First, I grouped the levels/layers into a series of analytical units (AUs), and then further combined them into combined analytical units (CAUs). I present the data by AU and CAU. The cultural stratigraphy is correlated directly to these temporal subdivisions in Table 3.

Table 3

Correlation between analytical unit (AU), combined analytical unit (CAU), and cultural association

CAU	AU-blocks C and D	Layer	Cultural affiliation
1	1	SD	Smithfield
2	2–4	HG and CPB	Ceramic Wilton
3	5–8	GAC	Developed Wilton
4	9–11	GAC	Developed Wilton
5	12–14	TG/CAC	Developed Wilton
6	15–23	TG/CAC	Developed Wilton
7	24–30	Upper CY	Classic Wilton
8	31–34	Mid CY	Lockshoek
9	35–38	Lower CY	Robberg

I recorded seven geologic layers in the 70 cm deep deposits at Blydefontein (Fig. 6). At the base of the excavations in the lower portion of Layer CY (CAU9), I recovered a Robberg assemblage with backed microliths, a few cores and bladelets, and a large scraper. Layer CY is composed primarily of alluvial silts and clays, and roof fall, but in the lower portion are thin organic layers (Brown-1 and Brown-2) that contain the Robberg component. These organic layers probably represent anthropogenic contributions (Bousman et al., 1998). The Robberg component at Blydefontein is dated toward the end of the Robberg time span at $11,850 \pm 150$ BP (OxA-8530; Table 4).

A Lockshoek assemblage (CAU8), midway in Layer CY, is separated from the Robberg component by sterile deposits. This component, dated by radiocarbon to 8541 ± 417 BP (SMU-1823), consists of large unifacial scrapers, rare cores, and large flakes.

The remaining archaeological components recovered from Blydefontein fall within Sampson's (1974) definition of Interior Wilton and Smithfield assemblages. A

sparse Classic Wilton assemblage (CAU7) at the top of Layer CY is separated from the underlying Lockshoek component by sterile deposits. This component is characterized by backed crescents and small end scrapers, but with no associated radiocarbon assays and very poor organic preservation. This predates a radiocarbon age of 4286 ± 149 BP (SMU-1852) in the overlying stratum (Layer CAC), and indicates that sparse occupations occurred in the mid-Holocene. This is similar to other Classic Wilton assemblages that date from 7000 to 5000 BP. An irregular and very abrupt upper boundary marking the termination of Layer CY is due to erosion, and suggests a break in the occupation record at Blydefontein.

The deposits above Layer CY represent a dramatic shift in sediment accumulation and most layers contain a significant anthropogenic contribution with dense accumulations of charcoal, ash, stone artifacts, and faunal remains. It is difficult to know if this shift in sedimentation is a reflection of changing organic preservation, intensity of site use, or site function. Layers TG/CAC

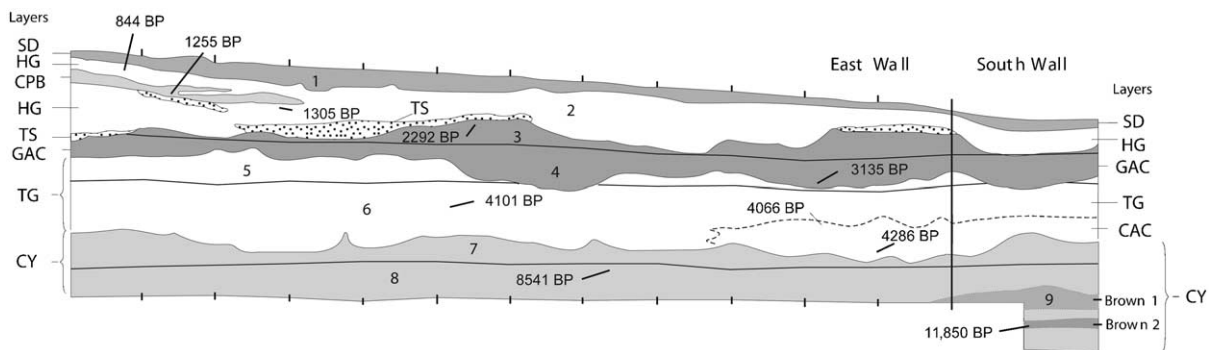


Fig. 6. Stratigraphic profile and associated ^{14}C assays of west and south walls of Blydefontein Rock Shelter.

Table 4
Radiocarbon dates from Blydefontein Rock Shelter

Stratigraphic layer	Excavation unit _{Level}	Lab No.	$\delta^{13}\text{C}$ corrected ^{14}C years BP	Material	Cultural association
HG	C2 ₂	SMU-1902	844 ± 119	Charcoal	Ceramic Wilton
CPB	C10 ₃	SMU-1925	1255 ± 109	Charcoal	Ceramic Wilton
HG	C42 ₃	SMU-1850	1305 ± 31	Charcoal	Ceramic Wilton
HG	C2 ₄	GrA-15195	1505 ± 50	Ceramics	Ceramic Wilton
HG	C9 ₄	GrA-15192	1810 ± 50	Ceramics	Ceramic Wilton
GAC	C58 ₅	GrA-15193	785 ± 50^a	Ceramics	Developed Wilton
GAC	C50 ₅	SMU-1853	2292 ± 117	Charcoal	Developed Wilton
GAC	D18 ₆	GrA-15194	1025 ± 50^a	Ceramics	Developed Wilton
GAC	D18 ₈	SMU-1849	3135 ± 33	Charcoal	Developed Wilton
TG/CAC	C18 ₁₄	SMU-1901	4101 ± 273	Charcoal	Developed Wilton
TG/CAC	D26 ₁₆	SMU-1851	4066 ± 55	Charcoal	Developed Wilton
TG/CAC	D17 ₂₀	SMU-1852	4286 ± 149	Charcoal	Developed Wilton
CY	C57 ₂₃	SMU-1823	8541 ± 417	Charcoal	Lockshoek
CY-Brown 2	South Wall (Level 27)	OxA-8530	$11,850 \pm 150$	Sediment	Robberg

^a Assay rejected due to suspected bioturbation.

and GAC contain Developed Wilton assemblages (CAU3–CAU6). These occur between approximately 4300–2300 BP, and are characterized by straight-backed bladelets and end scrapers. Layer TS caps Layer GAC. TS is a discontinuous, almost sterile, layer that consists mostly of decomposed swallow nests.

Ceramics are never common, but they are present in Layers CPB and HG (CAU2). Two small sherds were recovered from Layer GAC (CAU3). These two sherds are believed to have been displaced by bioturbation as their radiocarbon assays clearly do not match the charcoal ^{14}C ages for Layer GAC (see Table 4). The lithic tools in these layers are dominated by straight-backed bladelets, and end scrapers. Layer CPB, dated to 1255 ± 109 BP (SMU-1925), is almost devoid of artifacts and appears to consist mostly of dung. Analysis is now underway to help determine the source of the dung (Bousman et al., 1998). Even though a few Khoe sherds are present and these are associated with herder occupations in the Zeekoe Valley (Hart, 1989; Sadr and Sampson, 1999; Sampson, 1985, 1988; Sampson et al., 1989; Sampson and Sadr, 1999), the artifact assemblage in Layer HG contains more fiber-tempered ceramics than Khoe (herder) sherds. In the Zeekoe Valley, Sampson and Vogel (1996) and Sampson et al. (1997) suggest that hunter-gatherers made fiber-tempered ceramics. It is possible that both herders and hunter-gatherers used Blydefontein during this period. At this point, it seems reasonable to suggest that most of the occupants were hunter-gatherers manufacturing lithic tools similar to earlier Developed Wilton assemblages, but their fiber-tempered ceramics are similar to later Smithfield groups. In 1974 Sampson coined a term, “Ceramic Wilton” that might best apply. I will use that term here even though some of the occupants may have briefly herded sheep.

Deposition rates dramatically decline at the top of Layer HG after approximately 850 BP. The uppermost layer, SD, consists of loose sediment, scattered artifacts, and modern trampled sheep dung. The trampled sheep dung resulted from European stock corralled in the shelter during the last 200 years. The artifact assemblage in this upper deposit, composed mostly of long end scrapers and a few decorated fiber-tempered sherds, is Smithfield (CAU1).

Blydefontein assemblage patterns

Looking at the major technological shifts represented in the Blydefontein assemblages, a number of patterns emerge. Archaeologists working in Southern Africa have documented many of these patterns (e.g., Deacon, 1976, 1984; Deacon and Deacon, 1999; Mitchell, 2002; Parkington, 1984; Sampson, 1974; Wadley, 1987), while other variables are presented which reflect important information defined in lithic technological studies. A

review of these patterns is necessary because their temporal distribution at Blydefontein Rock Shelter forms the foundation of this analysis. However, it is not the definition of these patterns, but rather their interpretation that forms the contribution of this study.

In the discussion that follows, I consider previous interpretations that archaeologists have used to explain variability observed on specific tool forms, I review archaeological, ethnographic and historic evidence for the manufacture, use (including hafting) and repair of the specific tools, and I present an interpretation of the tool form based on the evidence excavated from Blydefontein.

End scraper length

At Blydefontein Rock Shelter variations in end scraper dimensions are clearly evident (Fig. 7) and these patterns are well known and widespread in Southern Africa (Deacon, 1984). Previous investigators offered numerous explanations to account for variations in end scraper lengths, and individual scholars' views changed through time or reflected multiple perspectives. For example, in the Orange River Scheme area, Sampson and Sampson (1967, p. 20) and Sampson (1970, p. 97) saw an increase through time in mean end scraper lengths, in part, as a response to shifts in lithic raw material usage. Small end scrapers were made more commonly of agate, jasper or other cryptocrystalline materials, and longer end scrapers made of hornfels. Many of the sites studied by Sampson such as Zaayfontein, Riversmead, and Glen Elliot (see Fig. 1) occur near the Orange (Gariep) River with gravel deposits that are the local source of cryptocrystalline materials (Butzer, 1971).

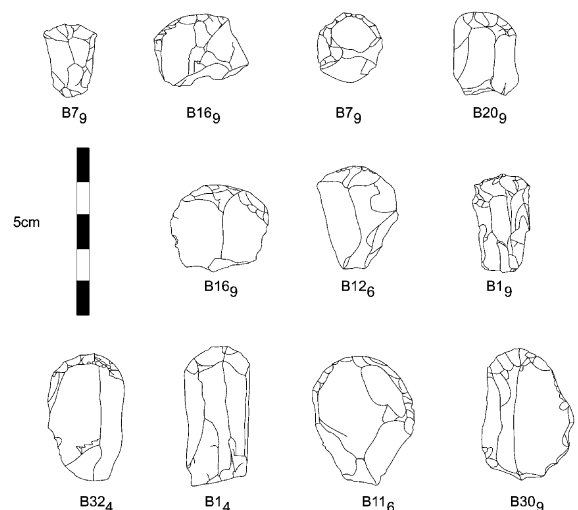


Fig. 7. End scrapers from Blydefontein (showing units and levels as subscripts).

Changes in access to raw materials through time probably were not a factor at these sites.

Sampson (1972, pp. 183–186) and Sampson (1974, pp. 295, 378) also viewed end scrapers as various types or styles associated with separate cultural entities: small end scrapers (less than 2.5 cm) associated with Interior Wilton, longer end scrapers (greater than 2.5 cm) are identified with Smithfield, and duckbill end scrapers with blunt lateral trimming are indicative of Lockshoek occupations. J. Deacon (1972, p. 15) and Deacon (1984, p. 282) elaborated on this concept in her analysis of scrapers from Wilton Large Rock Shelter where she argued she could identify stylistic *norms of manufacture* through the calculation of means and standard deviations of end scraper lengths. Thus, norms could be compared statistically. Clark (1959, p. 232), Deacon and Deacon (1980), and Sampson (1974, p. 298), all suggest that hafting influences end scraper size. Short end scrapers were hafted and long end scrapers were hand-held.

Khoisan hafting strategies are unusual for scraping tools (Fig. 8). Bound or slotted hafts are unknown. Generally, a large oval or conical lump of mastic, usually rendered from a plant source, is affixed to a wooden, bone, horn or even a mastic handle. The stone tool is pressed into the end of the mastic haft for a secure and rigid setting. Deacon and Deacon (1980) refer to this hafting technique for scrapers as *end mounting* (see Figs. 8A and B). All known stone tools hafted in this manner are classified as adzes, and were discovered from sites near the coast, e.g., Die Kelders, Steenbokfontein, Touw River Cave and unnamed Knysna and Plettenberg Bay caves (Clark, 1958, 1959, pp. 232–234; Deacon, 1966; J. Deacon, 1979; Hewitt, 1912, 1921; Inskeep, 1978, p. 56; Jerardino, 2001; Sampson, 1974, pp. 298–300; Schweitzer, 1979). The specimens from Die Kelders and Steenbokfontein are end mounted, but, instead of projecting straight out of the mastic, they are set at a slight angle (Jerardino, 2001; Schweitzer, 1979). Wear pattern analysis of one end mounted tool (see Fig. 8B) confirms that the stone bit of this specimen was used for chiseling and planing wood, and the mastic bears hand impressions (Binneman, 1983). Jerardino (2001) also reports a large cigar-shaped lump of mastic with finger impressions from Steenbokfontein. This unusual artifact was apparently used as a mastic source to repair items or touch-up hafting. Wear analysis of prehistoric adzes from Boomplaas Cave suggest that wood working was a primary function of adzes throughout the Holocene (Binneman and Deacon, 1986), and association between wood shavings and adzes in Western Cape sites supports this interpretation (Mazel and Parkington, 1981).

Only two artifacts, an end scraper from Boomplaas and a broken artifact mounted to a bird bone handle from a Plettenberg Bay cave (Deacon, 1966; Deacon and Deacon, 1980), are preserved with enough mastic to suggest that these artifacts were attached at an angle to a

handle (see Figs. 8D and E). Deacon and Deacon (1980) refer to this method of hafting as *side mounting*. End scrapers from other sites with good organic preservation such as Melkhoutboom, De Hangen, and Matjes River still have traces of mastic adhering to their surfaces (Clark, 1958, 1959, p. 201; Deacon, 1976; Hewitt, 1931; Parkington and Poggenpoel, 1971; Sampson, 1974, p. 298), and they are presumed to have been “side mounted.” On the single known side mounted end scraper (see Fig. 8D), the flake scars that form the bit terminate near the edge of the mastic, giving the impression that this scraper was intensively resharpened down to the haft (Clark, 1958). However, not all end scrapers were side mounted as Binneman’s (1982) wear-pattern study suggests that duckbill scrapers might have been end mounted.

Ethnographic and historical observations provide additional information regarding end scraper use. Ellenberger (1953, p. 92) observed San women in Lesotho using these tools for hide scraping. In a 1909 letter, written to Péringuey at the South African Museum in Cape Town, Dr. Daniel R. Kannemeyer from Burgersdorp in the Eastern Cape Province describes an interview with a Cape boy raised by Bushmen (Rudner, 1979, p. 6). This boy told him that typical Smithfield (duckbill) end scrapers, called *kuin* by eastern Free State San, were used as hand-held knives for skinning animals (Kannemeyer, 1890). Presumably, the unretouched lateral edge was used for cutting and the blunted scraper bit functioned as backing on a hand-held tool. Historical records also document the use of unmodified flakes for cutting and butchering tasks reflecting the use of expedient tool using strategies by protohistoric San (Bleek and Lloyd, 1911, p. 227; Rudner, 1979; Stow, 1910, p. 66). Task flexibility must have been a constituent of an end scrapers’ functional repertoire; thus, it is likely that *kuin* had multiple uses that included scraping.

This is further suggested by van Riet Lowe’s (1927) observations of an aged Bushman on the farm of Schaapplaats in the Winburg district (Free State) who still spoke a Khoisan language (Goodwin and van Riet Lowe, 1929, p. 180). This individual’s father had been a “wild” Bushman in the Winburg area, living by hunting and gathering, and was “tamed” but continued to live in the same area. This man described how his father made hand-held end scrapers for “paring down and shaping wooden clubs, bows, and arrows, cleaning skins, preparing karosses, and taking the meat off of bones,” and he also demonstrated a flaking technique where flakes were produced and trimmed into end and side scrapers (Goodwin and van Riet Lowe, 1929, p. 180). Flexibility was an obvious design goal of hand-held end scrapers, and it may be reasonable to expect a fair degree of variability in their forms.

Stow (1910, p. 73) describes two types of chipped stone tools used for scraping. One is notched and used to

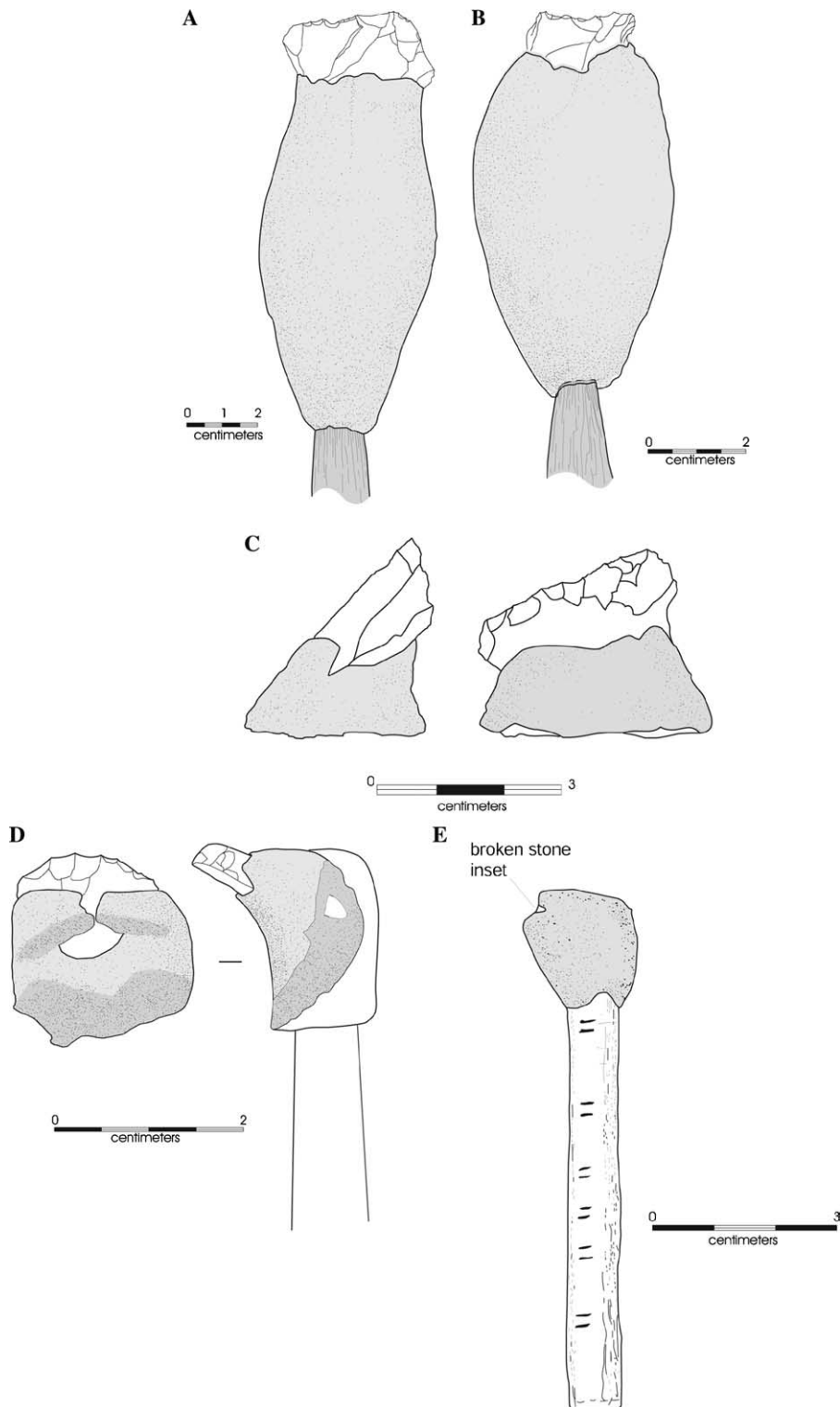


Fig. 8. Hafted scraping tools from Southern Africa: (A) Touw River Cave (after Inskeep, 1978, Fig. 13), (B) Plettenberg Bay Cave (after Clark, 1959, Fig. 51), (C) Stenbokfontein (after Jerardino, 2001, Fig. 2), (D) Melkhoutboom (after Deacon and Deacon, 1980, Fig. 1), and (E) Plettenberg Bay Cave (after Deacon and Deacon, 1980, Fig. 1).

shape wooden implements such as bows, clubs or kerries, darts, and harpoons (presumably bone points). The other is circular, 5–7 cm wide, hand-held, and used for scraping hides. The first would probably be classified as a hollowed or strangulated scraper common in Late Holocene assemblages that were called, previously, Smithfield N., and the second is a circular or convex scraper in Sampson's (1974) terminology. Neither artifact fits the description of an end scraper.

Following Dibble's (1987) analysis of Middle Paleolithic scrapers, I suggest that the final form of LSA end scrapers, especially the length, is primarily a function of intensity-of-use and resharpening, and not a reflection of norms of manufacture. Shott (1995) makes a similar case for Paleoindian end scrapers in the Midwest of North America, and Blades (2003) suggests a similar pattern for Aurignacian and Perigordian end scrapers in Southwest France. Furthermore, Morrow's (1997) analysis of North American Paleoindian end scrapers provides a model of end scraper "depletion" based on replication experiments. Morrow (1997, p. 77) argues that with repeated resharpening Paleoindian end scraper lengths become shorter, widths decline, bits become straighter, and bit angles become more obtuse. Many of these trends are apparent on LSA end scrapers; although for this essay I consider only end scraper length.

Along with the above observations, ethnoarchaeological studies of modern end-scraper manufacture and use support the model of end scraper reduction (Brandt, 1996, 1998; Brandt et al., 1996; Clark and Kurashina, 1981; Gallagher, 1977; Weedman, 2002). In Ethiopia, modern hide tanners sharpen hafted end scrapers at frequent intervals whenever the bits become dull or clogged with hide scrapings (Gallagher, 1977). However, Brandt et al. (1996), Brandt (1998), and Weedman (2002) show that initial manufacturing lengths vary by ethnic group, but these end scrapers were made by craft specialists in agro-pastoral societies using diverse sources of raw material acquired by direct and indirect means. It is unclear if Brandt's and Weedman's ethnic patterning is an appropriate analogy for the Blydefontein LSA egalitarian hunter-gatherers where the character of their lithic raw material sources do not vary as greatly and there is little evidence for ethnic divisions or ethnic replacement.

In this paper, I use end scraper length as a measure of resharpening intensity prior to discard. The occupants of Blydefontein discarded end scrapers in a wide range of lengths (see Fig. 7). Some analysts have measured or experimentally estimated the amount of material removed by resharpening as an estimate of the *depleted utility* of a tool (Blades, 2003; Frison, 1968; Kuhn, 1990). For example, Morrow (1997) suggests that each resharpening episode removes on average 2 mm of the bit edge. Alternatively, length provides an indication of a tool's remaining or *potential utility* (Shott, 1989,

1995). Presumably, all end scrapers could be expended to the same degree, irrespective of original length due to variations in blank shape. By considering the potential utility of end scrapers, it is logical that end scraper length can be strongly conditioned by hafting or lack of hafting. Even though a wide range of tool shapes and sizes could be mounted in a mastic haft, evidence of lateral trimming and ventral surface notching, possibly representing haft damage, are present on some Blydefontein specimens. Shott (1995) argues lateral trimming or backing was used to facilitate hafting. Hafting would allow for a more efficient and effective use of end scrapers.

It is assumed here that some LSA hunter-gatherers hafted end scrapers and others did not. Even though LSA end scrapers were probably multipurpose implements, resharpening the bit was the primary mode of repair. The final form, especially length, does not represent a preconceived shape or dimension of the tool upon its manufacture but rather its condition, perhaps exhausted perhaps not, upon discard. Longer or larger scrapers represent specimens discarded with more *potential utility* remaining, and length can be viewed as inversely related to curation (Bamforth, 1986; Nelson, 1991; Shott, 1989). Shorter end scrapers reflect more resharpening and more curation, and longer end scrapers indicate less curation.

I recovered no end scrapers from the Early Holocene Lockshoek (CAU8) or Late Pleistocene Robberg (CAU9) components, but large end scrapers, known as duckbill end scrapers, are well known in Lockshoek assemblages and a few small scrapers are known from Robberg assemblages (Deacon, 1984; Sampson, 1974). It is important to note that the Blydefontein Lockshoek component contains one large concavo-convex scraper (Fig. 9A), and a similar artifact is present in the Late Pleistocene Robberg component although it has been extensively resharpened (Fig. 9B). Even though it is a sample of two, it is possible that large scrapers, similar to the concavo-convex scrapers found in the Lockshoek, were manufactured by Robberg hunter-gatherers (Partridge, 1984), but they have undergone such extensive repair that their condition when discarded is visually different from Lockshoek scrapers.

Fig. 10 shows that average end scraper lengths are shortest in the Middle Holocene Classic Wilton assemblage (CAU7), while they generally increase throughout the remainder of the Holocene sequence from Developed Wilton to Smithfield assemblages (CAU6–CAU1). The mostly small standard errors illustrate that changes observed between the components are usually statistically significant. The Blydefontein samples in CAU5–CAU7 are very short and can reasonably be considered as exhausted or nearly so, and offering very little potential utility for future tasks.

The increase of average end scraper lengths through the Holocene is well documented throughout Southern

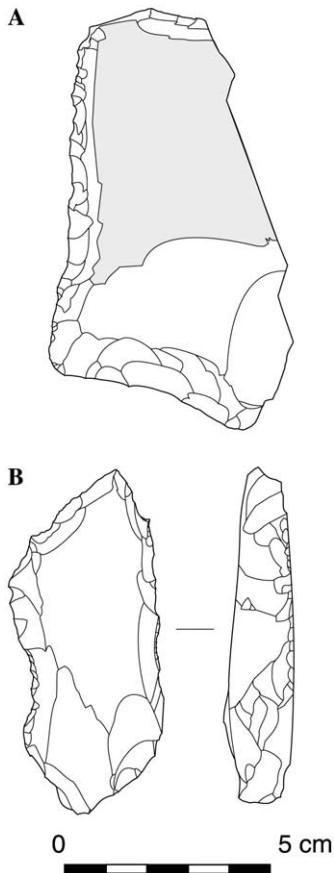


Fig. 9. Large scrapers from the Lockshoek (A) and Robberg (B) components at Blydefontein.

Africa, although the timing of this shift is not synchronous (Deacon, 1976, pp. 61–63; Deacon, 1984, pp. 283 and 301; Humphreys and Thackeray, 1983; Opperman, 1987, pp. 176–177; Sampson, 1970, p. 97; Sampson and Sampson, 1967, pp. 18–20). Also, after end scrapers made of nonlocal raw material at Blydefontein are removed from the calculations, this pattern in end scraper lengths is still present solely among hornfels end scrapers (Bousman, 1991). Thus a change in raw material use does not explain this pattern of changing end scraper lengths.

Raw material use

Lithic materials used by Blydefontein hunter-gatherers consist mostly of hornfels, metamorphosed shale that is ubiquitous in this region. Even though a systematic survey of Blydefontein Basin was not conducted, at least one hornfels outcrop is within a 10 min walk northwest of Blydefontein Rock Shelter, a few others are nearby, and many others certainly are present in the Kivvorsberg Range and surrounding areas. The multitude of sources found by the Orange River Scheme and Zeekoe Valley surveys (Sampson, 1972, 1985) demonstrate that hornfels is readily available throughout the region. The most common nonlocal lithic raw materials at Blydefontein are agates and jaspers. The nearest source of these materials are the gravels deposited in Orange (Gariep) River terraces no closer than 60 km to the north and northeast of Blydefontein (Butzer, 1971). These cryptocrystalline materials occur in greater frequencies on sites that are closer to the Orange (Gariep) River (Sampson, 1967b, 1970).

Archaeologists in Africa often infer that increased frequencies of nonlocal raw materials reflect greater range size and mobility, or increased exchange (e.g.,

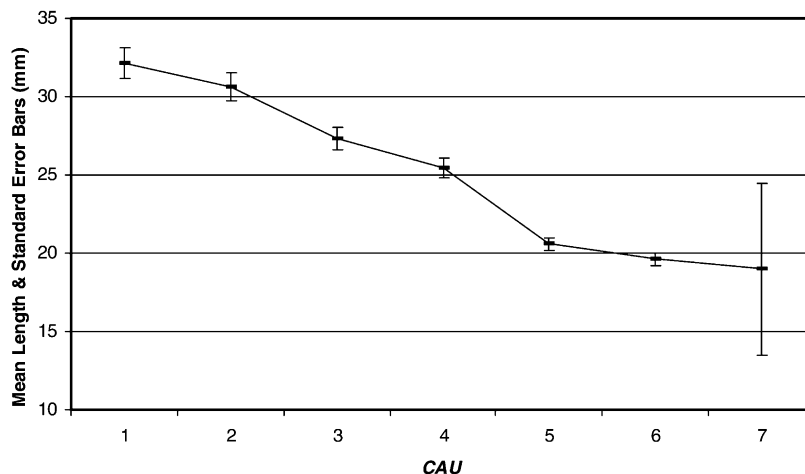


Fig. 10. End scraper lengths (mm) by combined analytical units (CAUs) at Blydefontein Rock Shelter with standard error bars. No end scrapers were recovered from CAU9.

Ambrose and Lorenz, 1990; Clark, 1980; Mitchell, 1996, 2000, 2002, 2003). Deacon (1976) suggested that increased frequencies of nonlocal raw materials in the Robberg were probably due to the existence of a few large groups of hunter-gatherers exploiting expansive ranges. Today the size of the groups could be debated, but large ranges and high mobility still seem reasonable for Robberg groups (Mitchell, 2002, pp. 130–131). In general, it is likely that the amount of raw materials transported from a given source will decline as the distance to its source increases, but distance alone cannot account for the variations through time in nonlocal raw materials at Blydefontein.

Wiessner (1977, 1982) proposed that a common way to reduce economic risk is to use social obligations to pool or share risk among Kalahari !Kung foragers. Wiessner (1977, pp. 211–214) identifies three ever-increasing spatial scales of risk (personal, local, and regional) which are absorbed by larger and larger social units (extended families, local bands, and regional populations). The Kalahari !Kung bond their social obligations through an exchange system known as hxaro. Hxaro also means ostrich eggshell beadwork, a commonly exchanged item (Mitchell, 2003, p. 36). Hxaro, the exchange system, provides a far-flung, but nevertheless, strong, network of complex social obligations that can be called upon by needy families during times of food shortage. Wiessner (1977, p. 60) and Yellen (1977, pp. 41–47) provide models of individual movements (band fission) in response to risk that is channeled by hxaro and kin ties. Wiessner (1977, 1982) and Wilmsen (1989) argue that hxaro is intimately linked with kinship obligations and mate recruitment, and as Mazel (1989) demonstrated the distance between spouse birth-places and the distance between hxaro partners in two !Kung groups (/ai/ai and 'cum!kwe) shows the spatial similarity between mate recruitment networks and hxaro networks (Fig. 11).

It is clear that during periods of low food productivity and greater risk, when sharing among the local !Kung band cannot compensate for shortages but before population abandonment, increased levels of exchange occur between regional populations (Wiessner, 1977, pp. 154–160). Eventually with continued shortages individual families move in with neighboring groups, with kin, or hxaro partners with more plentiful resources in surrounding band ranges.

Recently, Mitchell (2003) has discussed hxaro and exchange in Southern Africa. Mitchell importantly notes that not all Bushmen groups in the Kalahari practice a formal reciprocal system of gift-giving and that this system of exchange is limited to the !Kung and the Nharo, who call their similar system of exchange //ai. He shows that exchange, in some form, is common among Bushmen groups. Mitchell (2003, pp. 37 and 39) documents that many different items were exchanged or used in hxaro and these include dogs, beaded headbands, specularite, red ochre copper ore, salt, skin garments (colloq: karosses), skin bags, arrows, ostrich feathers, ivory and ostrich eggshell beads, horn, wooden vessels and utensils, dishes and spoons, iron, metal vessels, iron knives and spear heads, tobacco, cannabis, millet, honey, medicinal/magical plants, arrow poison, and glass beads. Mitchell (2003) proceeds to show that in both historic and modern contexts raw, unworked, materials were not commonly exchanged and usually finished products were the objects of exchange or gift-giving.

Ethnographic studies of exchange are important because they provide examples of artifact transportation outside of group ranges and across social boundaries. Wiessner's (1984) study of beaded headband exchange in the Kalahari discusses the redistribution of these items across social boundaries. If raw materials were

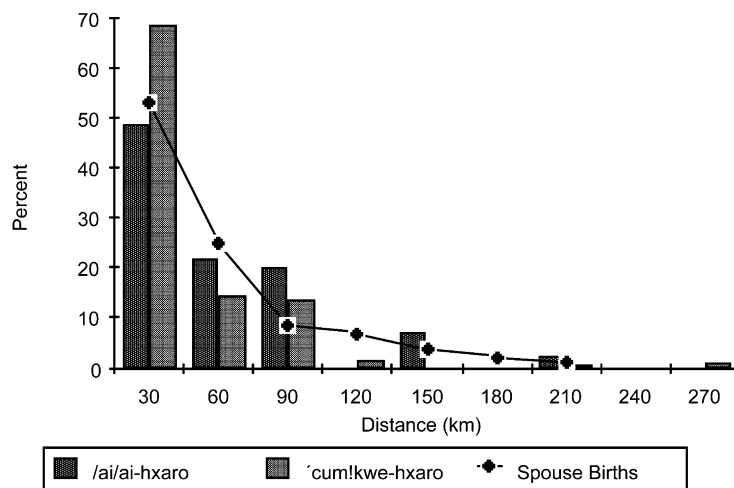


Fig. 11. Distances between hxaro partners in two exchange systems (/ai/ai and 'cum!kwe), and distances between spouse births (after Mazel, 1989).

exchanged through hxaro, the frequency of materials should decline with distance as the frequency of hxaro partners declines with distance. Since not all exchange is similar to hxaro, this reciprocal gift-giving model may not apply to all situations in the LSA.

Archaeological studies of material transport are also important. Wilmsen (1973) modeled the transportation of raw materials between groups across Paleoindian band boundaries. In this model, he predicted a reduction of exchanged (nonlocal) raw materials across these boundaries as a function of declining social interaction. This reduction in nonlocal raw materials is similar to the drop-off rate shown in the above patterns of spouse births and hxaro partners. I am not proposing that Blydefontein LSA hunter-gatherers used hxaro or another form of reciprocal gift-giving, but it is likely that many LSA hunter-gatherers in Southern Africa (Mitchell, 2003) practiced exchange. In the nineteenth century, Dunn (1931) observed San males in Bushmanland carrying lithic raw materials in leather bags for later tool manufacture, but I could find no example of flakable lithic materials exchanged. The question is how to determine if materials are transported directly because of greater mobility or through some form of exchange.

Meltzer (1989) discusses the difficulty in determining whether mobility or exchange influence the fluctuations of raw material frequencies in Paleoindian assemblages in eastern North America. Many of the same arguments apply to the African case, and it is clear that data equifinality is a significant concern. The primary problems are that exchange, range size, and mobility should all increase during periods of higher risk such as a major drought, and all these processes could influence equally the transportation of materials in a similar fashion.

Cryptocrystalline materials are never common at Blydefontein because of its distance from the Orange (Gariép) River terraces. Cryptocrystalline debitage occurs in its highest relative frequency in the Late Pleistocene Robberg component (CAU9) and is again relatively high in the Middle Holocene Classic Wilton component in CAU7 (Table 5). It is completely absent in the Early Holocene Lockshoek component (CAU8). The frequency of cryptocrystalline materials slowly decline through time in the Developed and Ceramic Wilton components (CAU6–CAU2), and again is absent in the Late Holocene Smithfield component (CAU1). One could argue that cryptocrystalline materials do not occur naturally in large enough pieces to be made into Lockshoek tools, but this is not the case for the Interior Wilton and Smithfield assemblages.

Cryptocrystalline materials occur in much higher frequencies among cores, scrapers, and backed tools than in lithic debitage (see Table 5). The lowest percentages are in backed tools and the highest in cores. If we accept that exchange items are usually manufactured and exchanged as finished items (Bleek and Lloyd, 1911, pp. 281, 283,

Table 5

Percent of cryptocrystalline materials in selected artifact classes for each combined analytical unit (CAU)

CAU	Cores	Scrapers	Backed tools	Debitage
1. Smithfield	—	0/8	—	0
2. Ceramic Wilton	0/2	0/29	0/9	0.13
3. Developed Wilton	0/3	3.8/26	0/28	0.14
4. Developed Wilton	22.2/9	5.2/58	0/51	0.52
5. Developed Wilton	13.3/15	3.4/29	3.3/30	0.75
6. Developed Wilton	23.7/38	11.7/137	3.9/103	1.22
7. Classic Wilton	42.9/7	40.0/15	20.0/10	3.70
8. Lockshoek	0/1	0/1	—	0
9. Robberg	12.5/8	—	0/3	4.49
Total	21.7/83	8.9/303	3.0/234	10,142

Blank cells indicates that artifact class was not present.

375, and 377; Mitchell, 2003; Wadley, 1989; Wiessner, 1977, 1982, 1983, 1984) and if stone-tipped arrows, scrapers mounted in handles, or other finished stone tools were transported and exchanged, it is unlikely that cores would consistently have the highest frequencies of cryptocrystalline materials since many tools could be produced from a single core. It is possible that unflaked cryptocrystalline nodules were exchanged because these materials were highly valued, but it appears that the raw material in the form of a core was the primary transported item. The low percentages of lithic debitage suggest that hunter-gatherers brought cryptocrystalline cores to Blydefontein in a near-exhausted condition and discarded when they obtained new material, probably hornfels, nearby. If prehistoric hunter-gatherers exchanged raw materials, then debitage should be more frequent. The observed pattern suggests that the groups that occupied Blydefontein Shelter were, in many cases, acquiring the raw material directly from the Orange (Gariép) River gravels, removing flakes as they traveled toward Blydefontein, and discarding exhausted cores on the spot.

Keeping these raw material patterns in mind, it is important to realize that Deacon's (1974, 1984) analysis of radiocarbon assays throughout the major regions of Southern Africa and more recent radiometric determinations (Bollong and Sampson, 1996; Bollong et al., 1993; Hart, 1989; Mitchell, 2002; Sampson et al., 1997, 1989; Sampson and Vogel, 1995, this paper) support a model of population decline in the Interior Plateau during the Middle Holocene's Classic Wilton phase. This pattern contrasts sharply with nearby regions such as the Cape Folded Mountains including the Suurberg and Winterberg where there is no obvious break in the temporal distribution of radiocarbon dates and, occupations during the Holocene (Deacon, 1974, 1976, 1984; Hall, 1990; Mitchell, 2002, p. 154).

In the nearby Zeekoe Valley Sampson (1985) recorded no Robberg components, 1307 Lockshoek

components with 29.1% (380) quarries, 5672 Interior Wilton components with 12.3% (696) quarries, 8849 Smithfield components with 15.5% (1372) Smithfield quarries, and 429 LSA sites with kraals. Blydefontein is the only site in the eastern Karoo to produce radiocarbon assays for Robberg and Lockshoek components. Unfortunately, Blydefontein only has a single determination for each of these two cultural periods, so the temporal spans of these occupations cannot be estimated and used to provide an indication of their spatial organization. Nevertheless, based on the Zeekoe Valley survey data and radiocarbon assays from Southern Africa as a whole, I can reasonably suggest that Lockshoek groups were more densely packed than Robberg populations.

Given that the Interior Wilton sites were created over a 3000 year period, if not longer, and the Smithfield occupations span no more than 1000 years, it is likely that Smithfield groups had higher population densities and exploited smaller ranges. Interior Wilton ranges could have been much larger particularly in the Classic phase when sites are rare in the Zeekoe Valley and excavated occupations are recorded only at Blydefontein and Zaayfontein shelters. At least among Smithfield and Interior Wilton groups, it appears that greater use of nonlocal raw materials occurs when ranges were larger and population densities lower, and this pattern may apply to the Lockshoek and Robberg as well.

Bladelets, bladelet cores, and backed bladelet production

Changes in technological efficiency can be related to optimal foraging models because of the inferred energy costs and savings. Four criteria are often used to measure efficiency: (1) reduced production time, (2) increased use-life, (3) faster task completion, or (4) increased production volume (Bousman, 1993). Kelly (1988) discussed the idea of technological efficiency for bifacial technologies and hunter-gatherer mobility in North America, but one of the earliest arguments for technological efficiency was framed in the context of the change from Middle Paleolithic flake technology to Upper Paleolithic blade technology in Europe (Leroi-Gourhan, 1943). The production of blades is seen as a shift toward improved efficiency because blades provide more total cutting-edge length than do flakes produced from the same stone (Sheets and Muto, 1972). One could argue that bladelets provide even more cutting-edge than blades because of miniaturization, and thus represent even greater technological efficiency (see Ambrose, 2002 for a different view). Since both flake and bladelet reduction strategies are present at Blydefontein, arguments for shifts in technological efficiency can be proposed.

The limited historical observations in Southern Africa for knapping stone do not provide evidence for the use of either bladelet or flake reduction strategies (Bleek and Lloyd, 1911, pp. 3, 15, and 227; Dunn, 1873, 1880; Goodwin and van Riet Lowe, 1929, pp. 180–181;

Rudner, 1979). Archaeological evidence is the only source of lithic reduction strategies. In the eastern Karoo, LSA hunter-gatherers produced bladelets by a simple technique. Prehistoric knappers decapitated elongated hornfels cobbles with one or two removals on one or both ends. The resulting flake-scar surface forms the striking platform for the bladelet core. The natural oblong-shape of most cobbles allows for the easy removal of bladelets systematically from the decapitated end of the core. Bladelets are easily recognized by a group of attributes: elongated rectangular shape, long straight edges, and dorsal-surface flake-scars, as well as small, often reduced, lipped platforms. The very small size of bladelet platforms at Blydefontein (Bousman, 1991) suggest that a punch technique was used (Ambrose, 2002). Alternatively, flakes are produced from single-platform and multi-platform cores. Usually flakes are roughly square to rectangular in shape, and have large single- and multi-faceted platforms as well as radial or multidirectional dorsal surface scar patterns. Soft or hard hammer techniques may have been used for flake production.

The stratigraphic distribution of bladelet frequencies in Fig. 12 shows that the greatest percentage of bladelets compared to flakes is in CAU6–CAU4 (4200–2500 BP) and, the lowest percentages are in the Lockshoek and Smithfield components (CAU8 and CAU1). Moderate frequencies occur in the Late Pleistocene Robberg component (CAU9). The ratio of bladelet cores to flake cores has a similar distribution to bladelets although CAU3 retains higher frequencies of bladelet cores (Bousman, 1991).

Dorsal cortex on debitage

The amount of cortex on debitage dorsal surfaces is often considered a crude measure of the degree of core reduction, but most studies are restricted to bifacial reduction sequences (Ahler, 1989; Butler and May, 1984; Collins, 1975; Henry, 1989; Muto, 1971; Vehik, 1985). Factors controlling the amount of core reduction are many, and not all of these are associated with the size and quality of the original block or nodule. One factor of immediate interest is the effect of source-to-site (transport) distance on the degree of core reduction found at a site. All things being equal, the further people carry a core and the longer they flake it, the more cortex the knapper will remove from it. Debitage from distant quarries should have less dorsal surface cortex than debitage from nearby sources. Thus the average amount of dorsal surface cortex should decline as hunter-gatherer territorial sizes expand, mobility increases, or as time between visits to sources increase. Implicit in this scenario is the assumption that nodules were not completely decorticated at the source before transportation.

All lithic debris from Blydefontein were classified into six ranked cortex categories (0 = 0% cortex,

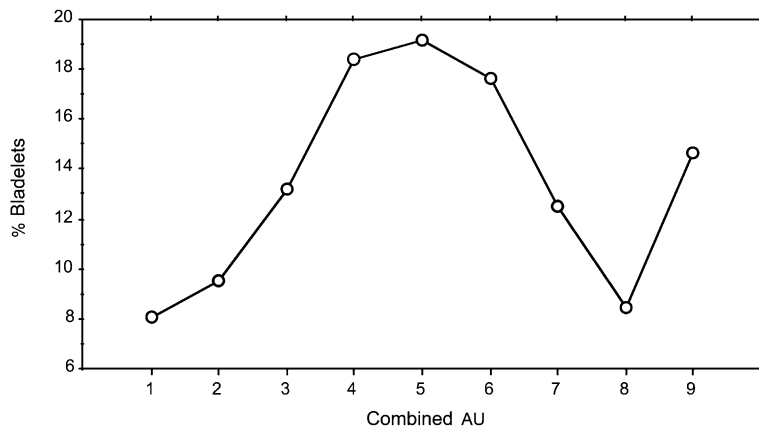


Fig. 12. Percent of bladelets in debitage by combined analytical units (CAUs).

1 = 1–25% cortex, 2 = 26–50% cortex, 3 = 51–75% cortex, 4 = 76–99% cortex, and 5 = 100% cortex). For each combined analytical unit (CAU) I calculated the average cortex ranks for all flakes and bladelets over 10mm in length. This eliminates very small resharpening flakes produced by retouching scrapers and other tools (Frison, 1968; Jelinek, 1966; Shafer, 1970; Shott, 1995). Fig. 13 is a line graph of the resulting mean cortex rank for flakes and bladelets from each of the nine Blydefontein Rock Shelter assemblages.

There is high cortex retention in the Robberg component (CAU9), and a significant drop in the Lockshoek (CAU8). Cortex retention again peaks in the Late Holocene Wilton components (CAU5 and CAU4), and then steadily declines to the Smithfield (CAU1) at the end of the Holocene. Initial decortification of cores at Goodlands (i.e., Lockshoek) quarries (Sampson, 1970, 1985; personal observation) might account for the very low retention in the Lockshoek

sample in CAU8. On the other hand, Interior Wilton raw material sources are usually weathered rubble cobbles in widely distributed terrace gravels or outcrop scree fans (Sampson, 1985, personal observation), and a higher cortex ranking would be expected. There is an obvious resemblance between the cortex retention curve and that for bladelet production rates (see Fig. 12). This implies that frequency of bladelet production has the greatest effect on cortex retention on debitage (more bladelets = more cortex), rather than distance-to-source or group mobility. I will return to this issue below.

Microlithic backed tools

At Blydefontein finished backed tools consist of backed flakes, curved backed bladelets, double backed bladelets, crescents or segments, and straight-backed bladelets (Fig. 14). Straight backed bladelets are the most common and these occur in four forms: simple

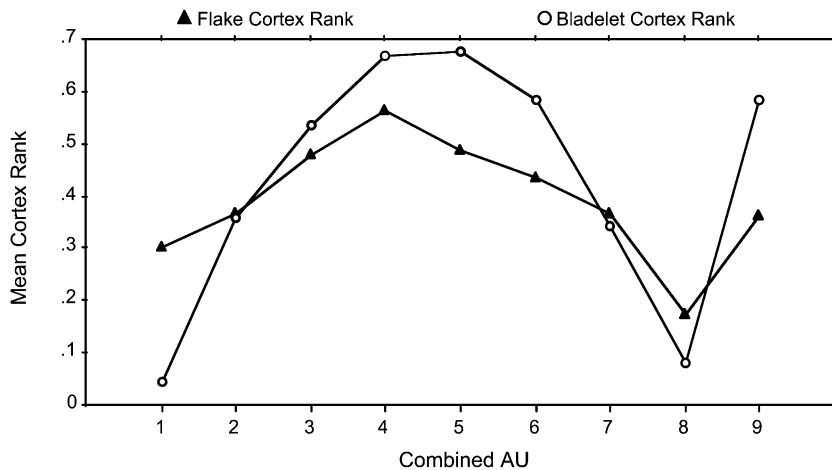


Fig. 13. Mean cortex rank for flakes and bladelets in combined analytical units (CAUs).

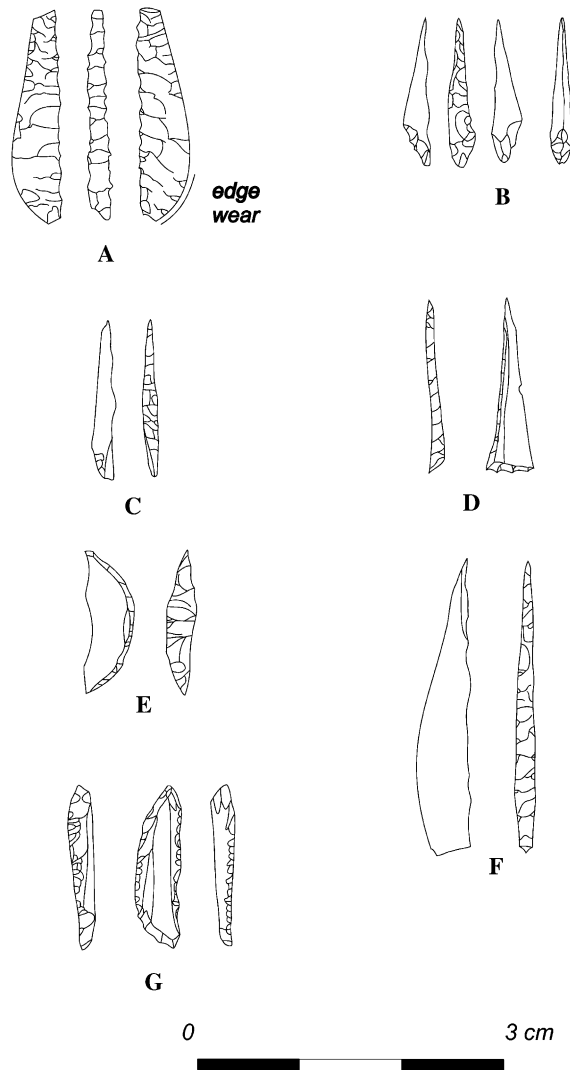


Fig. 14. Typical backed microliths at Blydefontein: (A) Ceramic Wilton pressure-flaked straight-backed bladelet, (B) Ceramic Wilton straight-backed bladelet with bifacial trimmed butt, (C) Developed Wilton straight-backed bladelet with unifacial trimmed butt, (D) Developed Wilton truncated straight-backed bladelet, (E) Classic Wilton crescent or segment, (F) Developed Wilton simple straight-backed bladelet, and (G) Robberg double-backed crescent or segment.

straight backed, unifacial trimmed butts, bifacial trimmed butts, and pressure flaked (Bousman, 1991; Close and Sampson, 1998a; Pease, 1993). Deacon (1976), Pease (1993), and Close and Sampson (1998b) provide production models for backed tool manufacture. These were based on the pioneering work of Movius et al. (1968).

The basic production procedure involved backing a bladelet on one side starting from the distal end working toward the proximal or platform end (Fig. 15). Usually the backing does not extend all the way to the bladelet platform. When the backing is extensive enough the bladelet is snapped. This is not a microburin technique, but creates both a backed bladelet and a proximal discard

fragment that Close and Sampson (1998a) call stubs. The proximal discard fragments, clearly produced during manufacture, are distinctive and easily recognized. Occasionally the backing is initiated at the proximal (platform) end and progresses toward the distal end. This technique produces a distal discard fragment or stub. Medial discard fragments are occasionally recovered as well. Close and Sampson (1998a, Fig. 11) indicate that pressure flaked specimens are first pressure flaked and then backed. The single finished specimen from Blydefontein shows that pressure flakes were also detached from platforms created by backing, suggesting that the pressure flaking occurred after the backing, or in two steps before and after the backing.

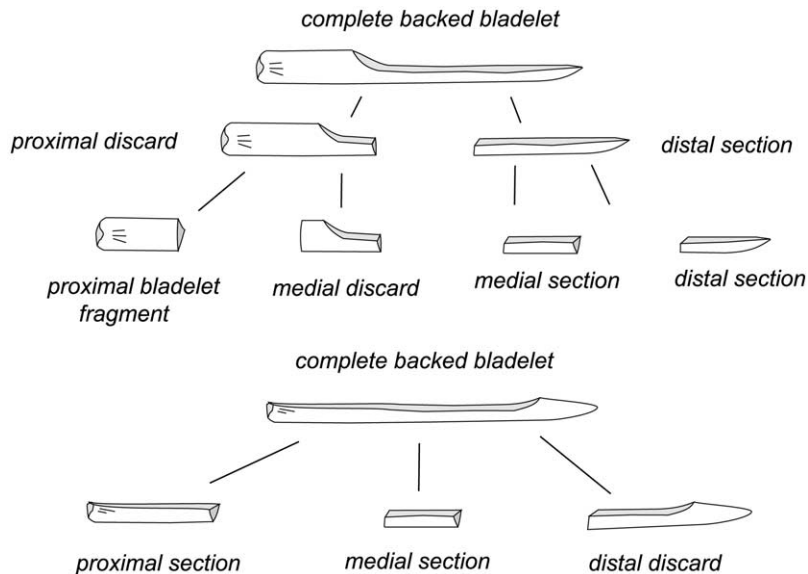


Fig. 15. Backed tool production sequences (after Pease, 1993; Close and Sampson, 1998a).

Ethnographic and ethnohistoric evidence from Southern Africa indicates that microlithic backed tools were components of composite arrow armatures (Bousman, 1997; Clark, 1959, 1977; Deacon, 1984; Goodwin and van Riet Lowe, 1929, p. 181; Goodwin, 1945; Rudner, 1979; Rudner and Rudner, 1957; Sampson, 1974). However, Binneman's (1982), Wadley and Binneman's (1995), and Binneman and Mitchell's (1997) wear-pattern studies demonstrate that LSA hunter-gatherers used microliths for cutting tasks as well. These cutting tasks could have been conducted while microliths were hafted on projectile foreshafts. A wide variety of lithic sources were used for microliths, but most of the extant hafted ethnographic specimens are made of glass (Binneman, 1994; Goodwin, 1945; Rudner, 1979; Stow, 1910).

The only known manner of hafting backed microliths in Southern Africa was by mounting two matching backed microliths in a wad of mastic stuck on the end of a bone or wood foreshaft (Fig. 16). The blunt backing was pressed into the mastic so that the points and the cutting edges of the backed microliths projected beyond the mastic. Recent wear-pattern analysis of Robberg bladelets at Rose Cottage Cave suggests they might have been mounted in a slotted haft (Binneman, 1997) and Binneman and Mitchell (1997) provide additional evidence of hafting. However, direct evidence of slotted hafts in the form of a preserved hafting element is lacking.

van Riet Lowe (Goodwin and van Riet Lowe, 1929, p. 181) interviewed an old Bushman in 1927 whose father showed him how to make stone points fixed to a mastic haft. Dunn (1873, p. 34) interviewed a /Xam

woman in 1872 at a place called Struis Pits on the Zak (Sak) River in Bushmanland (see Fig. 1) who showed him how "...arrow-heads are deftly broken by striking one stone with another. At first a few light strokes are given to guide the fracture. Then a smarter one is given to detach the chip. Two small chips, whose sharp points are exactly of the same form and size, are cemented on to the arrow tip, one on each side. The points of these chips must coincide to form the piercing end." Later Dunn (1880, p. 16) elaborated on this demonstration and said "...two small triangular flakes were detached from a piece of hard stone, they were as nearly alike as possible, the point of the shaft was flattened and coated with resin obtained from a small pelargonium [plant], this resin is softened by heat, and the two flakes pressed on the opposite sides of the flattened tip of the shaft, the points being carefully brought together; the bases of the arrow-heads were some distance apart." Binneman (1994) recovered a single stone hafted in mastic at Adam's Kranz Cave, and this demonstrates that mastic hafts were used prehistorically in the Eastern Cape. This method is distinctly different from the slotted foreshafts employed for microlithic tools in Europe, Southwest Asia, and North Africa. No slotted hafts have been found in Southern Africa.

The use of poison is recorded with cylindrical bone points with link shafts, bone bones with quill barbs, triangular flat-shouldered bone points, and the small metal points now used in the Kalahari (Clark, 1959, 1977; Deacon, 1984; Lee, 1979; Rudner, 1979; Schapera, 1925, 1927, 1930; Silberbauer, 1981; van Riet Lowe, 1954; Van Rippen, 1918; Webley, 1994). However, there

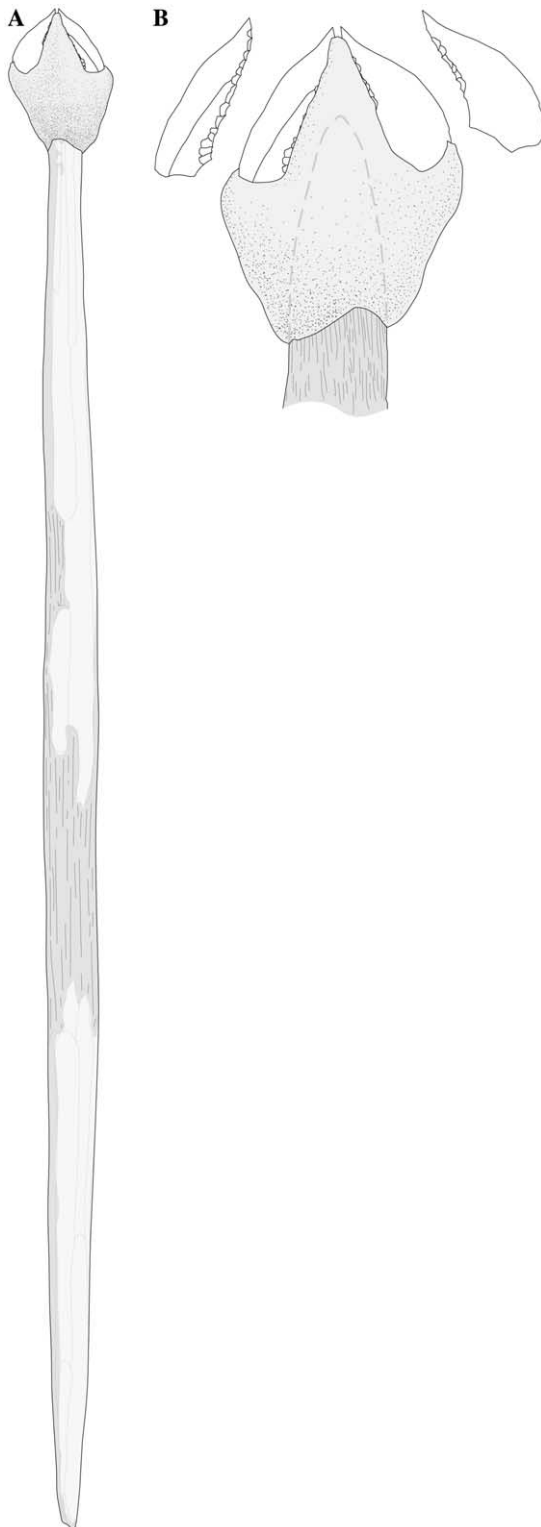


Fig. 16. Hafted backed microliths: (A) foreshaft with hafted microliths, (B) enlargement of hafted microliths (after Goodwin, 1945, Fig. 2).

is no clear indication that poisons were habitually used with arrows armed with stone points (Binneman, 1994; Clark, 1959, p. 224, 1977). The one known example seemingly was reused as the mastic holding the stone microlith covers a coating of poison, apparently applied during a previous use (Clark, 1977, p. 136), so the association is unclear. Stone microliths are believed to break after penetrating the animal and cause greater bleeding (Mossop, 1935, p. 179; Rudner, 1979, p. 5). Increased bleeding through a wound might flush out poison, and reduce its effectiveness. It is important to mention that no evidence for the use of bow-and-arrows exists for Lockshoek or Robberg assemblages and it is often assumed that these groups used spears perhaps with spear throwers (Ambrose and Lorenz, 1990; Mitchell, 1988; Parkington, 1998). Rock art and recovered artifacts clearly show that Smithfield and Wilton groups possessed bow-and-arrow technology (Deacon, 1963; Lewis-Williams, 1981; Manhire, 1993; Manhire et al, 1985; Vinnicombe, 1976).

The reliability of microlithic arrows is unknown, but one way to analyze this variable, perhaps experimentally, would be to model or estimate experimentally the different reliability rates of the individual components in composite tools and parallel tool systems (Meredith, 1980). Hayden and Gargett (1988) and Oswalt (1976) indicate that hunter-gatherers produce specialized tools with more components to increase resource procurement, processing, or manufacturing efficiency. But as a single tool becomes more complex with more components, the tool is likely to fail because of the malfunction of one of the components.

Fig. 17 illustrates an example. If a tool has three interdependent components, e.g., chipped stone point, mastic haft, and shaft, and the average reliability of the individual components, let me say, is 95, 90, and 85% respectively, then the reliability of the whole tool is only ~73% (overall reliability = $0.95 * 0.90 * 0.85$). Simpler tools may be less likely to fail, but they are probably more costly to repair and could be less effective. For example, Odell and Cowan (1986) discuss the improved effectiveness of bifacial chipped stone projectile points over unaltered pointed flakes.

One strategy used by hunter-gatherers to overcome this problem of diminished reliability is to use redundant parallel tools such as multiple spears carried together on a

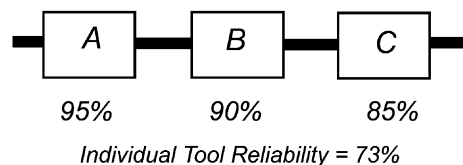
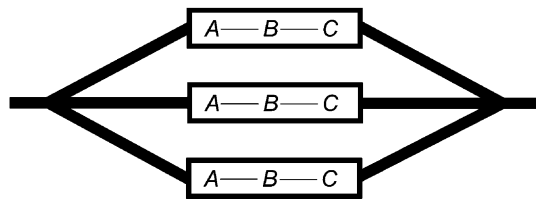


Fig. 17. Reliability of tool design for interdependent components in a series.



Individual Tool Reliability = 73%

Total System Reliability = 98%

Fig. 18. Reliability of tool design for independent or redundant parallel components.

single hunting foray by an individual hunter. In Fig. 18 if three tools with the same 73% reliability rating as the hypothetical tool discussed above are used as redundant backups then the overall weapon reliability of that hunter significantly increases to ~98% [reliability = $(1 - (1 - 0.73)^3)$]. Unquestionably, composite tools used in parallel as backups provide higher levels of efficiency plus greater degrees of reliability than any other technological combination.

Gould (1967, pp. 43–44) provides an excellent example of the problems encountered because of tool failure by Aborigines in the Western Desert of Australia. In this case a Pintupi group failed to bring ammunition for their rifles on an extended foray. Instead they hunted with multiple spears and a spear thrower (parallel systems). During an ambush hunt of emus at a waterhole, the base of one spear broke in flight from the force of the spear thrower, and the spear missed the animal. Anthropologists occasionally make these types of observations, but rarely do they publish quantitative data on success rates and tool failure.

To return to the Blydefontein data, among backed microliths, breakage rates may reflect the ratio of broken or complete discarded extractive tools (microlithic projectile points). I excluded the proximal, medial, or distal discards from this calculation as they are assumed to be discarded during the manufacturing process. Furthermore, I assume that the discarded backed microlithic tools in Blydefontein Rock Shelter consist of those broken during manufacture, as well as those broken while hunting but discarded back in camp while repairing projectiles. Finally, I assume in this analysis that the frequency of microliths broken during manufacture was fairly constant through time. It is also important to realize that when projectiles needed repair it might be because the mastic haft was cracked or foreshaft damaged, and not necessarily because the backed microliths were broken. Thus complete unbroken microliths could be discarded while still attached to damaged mastic hafts or foreshafts. It is also possible that some microlith fragments may have been brought back to sites in animal carcasses. Backed microliths apparently were not

resharpened while mounted in their hafts; they were replaced. This replacement strategy is totally opposite to the rejuvenation model proposed by Ahler and Geib (2000) for Paleoindian Folsom points. Manufacture of backed microliths would require very little time, and replacements could have been remounted quickly into the same or new mastic haft.

Close and Sampson (1998c) offer an alternative view. They argue that most broken LSA backed microliths in nearby Zeekoe Valley rock shelters are the result of manufacturing breaks because they co-vary with debitage concentrations. They also suggest that used microliths would not have been discarded in a habitation area because of the danger presented by residual poison on these tools. However, it is unknown if LSA knappers produced these debitage concentrations for the manufacture of microlithic tools or for other stone tools, in part, because a technological analysis of this debitage is lacking. Evidence from Blydefontein (see Fig. 11) and Haaskraal Rock Shelter (Hart, 1989) in the nearby Zeekoe Valley suggest that bladelet production was low during the periods when most of the excavated Zeekoe Valley sites were occupied, i.e., Ceramic Wilton and Smithfield. If the broken microliths at Zeekoe Valley sites are a result of manufacturing breaks then one would expect evidence of bladelet production in those debitage concentrations. As these are small shelters, it is also possible that composite armaments were repaired, and broken microlith fragments were discarded at the same location where other tools were manufactured, especially if poison was not used. It is also possible that these concentrations are a result of floor sweeping/cleaning by the prehistoric inhabitants.

Two specimens housed in the South African Museum have broken glass and stone insets (Clark, 1977, pp. 135–138), and presumably the breakage occurred through use. Along with the wear-pattern studies of Binneman (1997), Wadley and Binneman (1995) and Binneman and Mitchell (1997), an unsystematic examination of a few of the Blydefontein specimens did show evidence of edge wear (see Fig. 14A), and it seems unlikely that microliths coated with poisons would be used for cutting tasks. Clearly, discard-after-use was at least one trajectory into the archaeological record. Nevertheless, I strongly agree with Close and Sampson (1998a) that a systematic wear-pattern analysis should help determine to what degree backed tools were used or discarded because of manufacturing breaks.

In a limited fashion, Close and Sampson's (1998c) model can be tested with data from Blydefontein. If the ratio of broken backed microlithic tools is the result of manufacturing breaks then there should be a correlation with the frequencies of proximal, medial or distal discard fragments (stubs) and the frequencies of broken backed tools. Table 6 shows the percentage of proximal and distal discard fragments among all backed items, and the percent

Table 6
Percent of discard fragments and percent of broken backed tools by combined analytical unit

CAU	% Discard fragments	<i>n</i>	% Broken backed tools	<i>n</i>
2	30.8	13	88.9	9
3	21.1	38	89.3	28
4	20.9	67	88.2	51
5	8.57	35	93.3	30
6	17.6	131	80.6	103
7	9.1	11	60.0	10

of broken versus complete backed microlithic tools. A linear regression analysis produced an insignificant correlation ($r^2 = 0.185$; p value = 0.3947). The sample sizes are very small in CAU2 and CAU7, but eliminating these from the comparison does not alter the basic pattern. While there is an increase in the percent of discard fragments through time, it is not correlated with an increase in broken backed tools. This supports the inference that the manufacturing breaks can be viewed as a constant and that the variation in breakage rates primarily reflect the changing numbers that were discarded in an unbroken state after use.

Factor analysis of the Blydefontein Interior Wilton assemblages and further considerations

As an exploratory exercise, I submitted the above variables to a factor analysis. I included only the Interior Wilton assemblages from CAU2 through CAU7 in the factor analysis because of small sample sizes in the other components. The analysis identified two factors (Table 7), and Fig. 19 illustrates the temporal distribution of the factors. My discussion of the factors is reverse to their numerical order.

The second factor (see Table 7) consists of negative loadings on end scraper length, and positive loadings on the percent of cryptocrystalline raw materials and the percent of complete backed tools. The pattern indicates that increased use of nonlocal raw material, possibly reflecting greater mobility and larger territories, is associated with more intensive resharpening of end scrapers (maintenance tools) and high frequencies of discarded complete backed tools (extractive tools). This second factor presents the exact pattern that the ethnographic model (see Table 2) illustrates between forager and collector technological strategies.

Table 7
Factor loadings and proportion of artifact type variance (communality) explained by factor analysis

Artifact type	Factor 1	Factor 2	Communality	Variable complexity
% Complete backed bladelets	-0.437	0.863	0.935	1.481
% Agate in lithic debris	-0.263	0.949	0.970	1.153
Mean end scraper length	-0.387	-0.892	0.954	1.363
Mean flake cortex rank	0.864	-0.312	0.844	1.257
Mean bladelet cortex rank	0.977	-0.208	0.997	1.090
% Bladelets	0.974	0.186	0.984	1.073
Proportion of common variance	0.539	0.461		

Factor analysis uses principal components with a varimax orthogonal rotation. Also listed are proportion of common or explained variance for each factor, and variable complexity. Variable complexity indicates how many factors account for variable's (artifact type) communality. Significant loadings shown in bold.

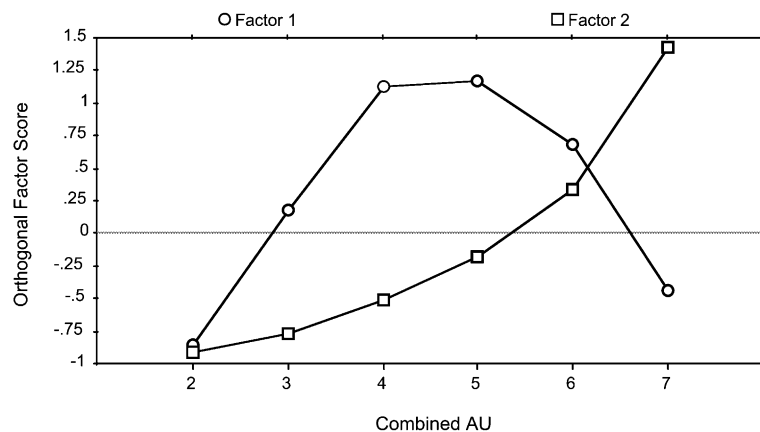


Fig. 19. Factor 1 and Factor 2 scores for assemblages from combined analytical units.

The first factor (see Table 7) is characterized by positive loadings on the percent of bladelets, mean flake cortex rank, and mean bladelet cortex rank. No correlation exists between bladelet production and evidence for mobility as reflected by changes in the abundance of nonlocal raw materials. Thus bladelet production (technological efficiency) cannot be linked to the ethnographic model (see Table 2), and the patterns suggest that bladelet production is associated with other variables.

Bladelet production reconsidered and projectile reliability

Bar-Yosef and Kuhn (1999) suggest that the shift to blade and bladelet production is related to the manufacture of composite tools, and that blades or bladelets are standardized tool blanks. In their formulations, expensive composite tools would be most common during periods when access to key resources was restricted. The temporal patterning observed among the bladelets hints that the first part of the Bar-Yosef and Kuhn model may apply to the Blydefontein example, but the latter portion does not. It can be suggested that bladelets were produced as blanks for specific tools, such as straight-backed microliths. These microlithic tools are made exclusively on bladelets. If this argument holds, then when straight-backed microliths are manufactured bladelet production should increase. A regression analysis displayed in Fig. 20 demonstrates a clear relationship for each CAU between the percentage of straight-backed microliths among all backed tools and the percentage of bladelets in the debitage category. A similar relationship holds for straight-backed microlith percentages and the percentage of bladelet cores (see Fig. 20). I argue that the rate of bladelet production is determined by the need for bladelets for manufacturing straight-backed microliths

and not by other factors. Bladelets are just tool blanks for Wilton and Smithfield knappers.

The early portion of the Interior Wilton sequence, during the Classic and early Developed Wilton components (CAU6–CAU7) in the Middle Holocene, has more backed crescents and these could have been made from a flake or bladelet. At the end of the sequence the reason for the decline in backed armatures is uncertain. At this time, tanged projectile points, some bifacially pressure-flaked (Close and Sampson, 1999; Mitchell, 1999), were manufactured, and this could account for part of the decline. At Glen Elliot Shelter, Sampson (1967a) linked this decline to an increase in the use of cylindrical bone arrow points as armatures. However, this relationship cannot be demonstrated at Blydefontein, but the Smithfield sample is very small. Pease (1993) argues that this reduction in backed microlith production does not occur in the nearby Zeekoe Valley sites either. Apparently by the early contact period, LSA hunter-gatherers were not making backed microliths in the Zeekoe Valley (Close and Sampson, 1998b). Instead these Zeekoe Valley hunter-gatherers were making cylindrical bone points lashed with porcupine quill barbs that were probably coated with poison. Thus by at least the protohistoric portion of the LSA in the eastern Karoo, microlithic production had ceased, and bone projectiles were used instead of microliths.

Along with some Smithfield assemblages, bone points are common in Albany assemblages, the coastal equivalent to Lockshoek (Deacon, 1978, 1984; Mitchell, 2002), however bone is very poorly preserved in the Lockshoek assemblage at Blydefontein and it is the only excavated Lockshoek assemblage in the eastern Karoo. Our current knowledge does not provide a reliable indicator of bone technology during the Lockshoek period, but it is significant that evidence of stone projectile armaments is

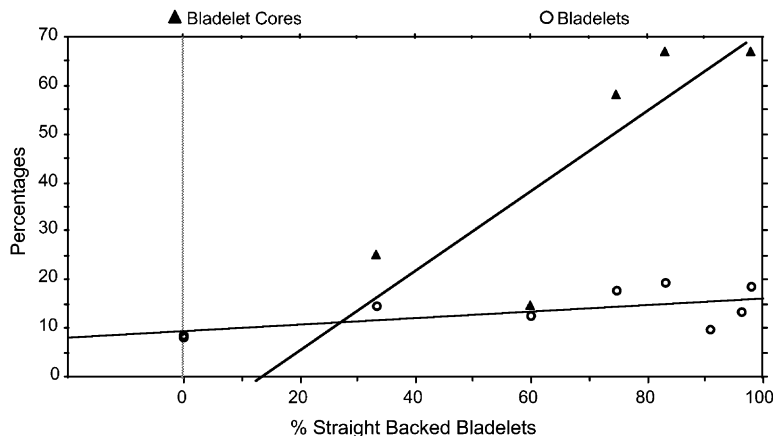


Fig. 20. Scatterplot and linear regression between straight-backed bladelets with bladelets ($r^2 = 0.391$, $p = 0.072$) and bladelet cores ($r^2 = 0.673$, $p = 0.089$).

lacking in Lockshoek assemblages. This might imply that bone or perhaps wood was used instead.

Recent ethnohistoric and experimental research on the raw material properties, manufacture and repair techniques, and performance characteristics of bone, antler (not considered in this discussion because of its absence in Africa) and stone points suggest that these materials differ dramatically (Ellis, 1997; Knecht, 1997). The more important results of Knecht's (1997, p. 206) research indicate that stone points cause more bleeding, can be quickly replaced, and take less time for manufacture. On the other hand, bone points are more durable, require repair less often, and bone projectiles in the Southern African record had fewer component parts. Ellis' (1997) review of stone and bone projectile point use by North American, Australian, and South American groups supports Knecht's conclusions, although Ellis suggests that stone point replacement rates were so high as to constitute considerably more work overall than incurred in bone points. One issue is clear: the costs and benefits between stone and bone projectile points differ, and each has advantages and disadvantages.

At Blydefontein, bladelet production is emphasized when straight-backed microliths are used for projectile armatures. When bone points or crescents are used, bladelet production declines or ceases. This pattern applies for spear (Robberg and Lockshoek) and bow-and-arrow (Wilton and Smithfield) projectile systems.

Even with the analyses of Ellis (1997) and Knecht (1997), and the composite models presented above, it is not clear why these changes occur. The shift from stone projectiles to bone points suggests a functional reason. Perhaps poisoned bone points were more affective for hunting larger game.

The shift from crescents to straight-backed microliths to tanged points is less obvious. One possibility is that the differences in stone point form represent stylistic patterns as documented by Wiessner (1983) among modern Kalahari San metal points, however Close and Sampson (1999) suggest this would not fit the tanged point regional distribution pattern. Alternatively, Wadley (1989) argues that a diversification on backed tool forms is stylistic, and a response to environmental stress and the apparent increase in hvaro exchange that occurs during economically stressful conditions among Kalahari San groups. Fitzhugh's (2001) model which links environmental stress and technological innovation, supports Wadley's argument.

The Blydefontein data presented here support a limited model for the use of an efficient technology. Bladelets are blanks for the production of straight-backed microlithic tools resulting in reduced production time because the number of usable pieces is higher for a given amount of raw material. Although information is lacking, it is also possible that bladelet production could offer quicker manufacture of backed microliths and

increased use-life of composite projectile point armaments.

Economic exploitation patterns and technology

Identifiable plant remains at Blydefontein were not preserved because of occasional wetting and drying of the shelter deposits. An inspection of the NISP faunal data from Blydefontein indicates that care must be taken in analysis and interpretation, because the sample sizes are small (Fig. 21). One intriguing, but not entirely secure, interpretation is possible. Small and small/medium bovids tend to increase while the smaller animals especially dassies (a woodchuck-sized mammal that live in colonies in cliffs and rock outcrops) and lagomorphs decrease as the Factor II scores decline in the middle to late portion of the LSA sequence. This suggests that the shift to a forager-like technological pattern is associated with a shift toward the exploitation of more bovids, and fewer rabbits, hares, and dassies. The relatively high percentages of large and large-medium bovids in Lockshoek and Classic Interior Wilton assemblages (CAU7 and CAU8) in the Early and Middle

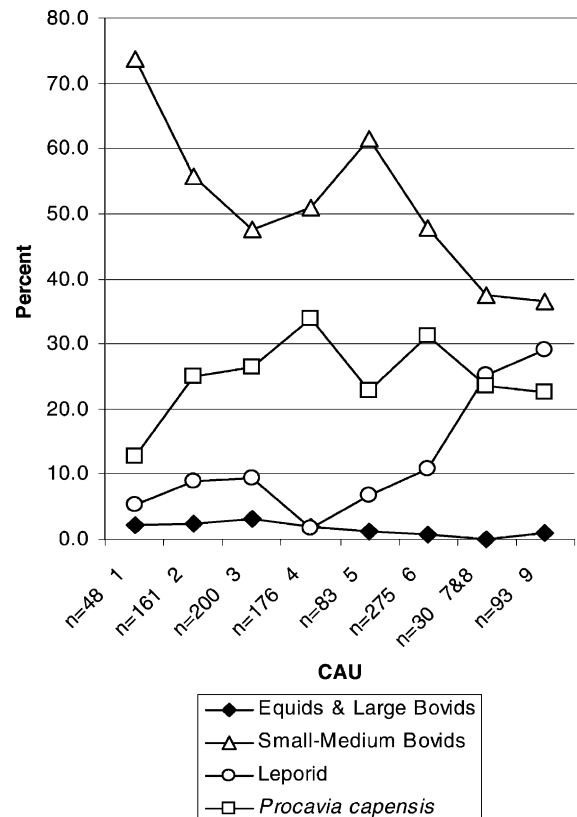


Fig. 21. Faunal NISP percent and sample size by CAU at Blydefontein Rock Shelter.

Holocene are probably due to preservation bias and the sample sizes are very low in these components.

As suggested by H. Deacon (1972), it is possible that smaller species were trapped rather than hunted, although no direct evidence of trapping exists in the Karoo. Dassies are easily killed. My excavation crew, consisting of local farm laborers, killed dassies in the cliffs (colloq: krantz) above Blydefontein during our lunch breaks by throwing stones.

While not robust or secure, this pattern is similar to predictions of optimal foraging models (Bettinger, 1991; Smith and Winterhalder, 1992) which propose that hunter-gatherers add resources with lower rankings (usually smaller species) to the range of exploited resources or exploit these smaller resources in greater frequencies when economic productivity of higher-ranked prey declines. The excavation of sites with better organic preservation will be needed to answer this issue, however an indirect measure is possible with paleoenvironmental data.

High resolution responses to environmental change

A distinctive pattern is present if we look at the paleoenvironmental record from Blydefontein Basin and Blydefontein Rock Shelter in relation to end scraper lengths. No other formal tools, such as microliths, occur in great enough numbers to be included in this analysis. Past environmental changes are monitored by ostrich eggshell $\delta^{13}\text{C}$ measurements. Ostrich eggshell fragments are directly associated with the artifact samples from the archaeological excavations. The eggshell was selected from a single vertical column. Detailed paleoenvironmental studies are based on pollen, diatom, stable carbon isotope, mammalian faunal and microfaunal, and

molluscan faunal analyses from nearby geological sites and hyrax dung middens (Avery, 1988; Bousman, 1991; Bousman et al., 1988; Bousman and Scott, 1994; Scott and Bousman, 1990; Scott et al., 2005). These independent proxy sources of environmental change corroborate the ostrich eggshell $\delta^{13}\text{C}$ patterns (Fig. 22). Unlike many paleoenvironmental indicators from archaeological sites, human selection does not influence the $\delta^{13}\text{C}$ ostrich eggshell values.

When the ostrich eggshell carbon isotope ratios decline toward a stronger C_3 pattern, then grass declines and Karoo bossies increase in the pollen spectra, and modern botanical evidence (Bousman, 1991; Scott et al., 2005) suggests that this is due to drought conditions (see Fig. 22). When the carbon isotope ratios increase toward a balanced C_3 – C_4 pattern, then wetter conditions with better grass cover are experienced locally. This is the reverse of most paleoenvironmental interpretations of $\delta^{13}\text{C}$ values, but this is due to the mixture of C_3 and C_4 grasses in grassveld communities and the dominance of C_3 bossies in Karoo veld biomass. Bossies increase during droughts while grasses, both C_3 and C_4 species, are more common during wet episodes.

If mean end scraper lengths are plotted along with the ostrich eggshell stable carbon isotope ratios, a rough correspondence is evident (Fig. 23). I should point out that there is a slight lag effect in some of these patterns, but the correspondence is close enough to propose a linkage. The apparent lag is probably a result of the single eggshell column correlated to artifacts recovered from all units across the site. Additionally, there is an apparent difference in the end scraper length measurements illustrated in Figs. 10 and 23. This is due to variations in sample size in the individual analytical units (AUs) versus the much larger samples in the combined analytical units (CAUs) The pattern illustrated by AU

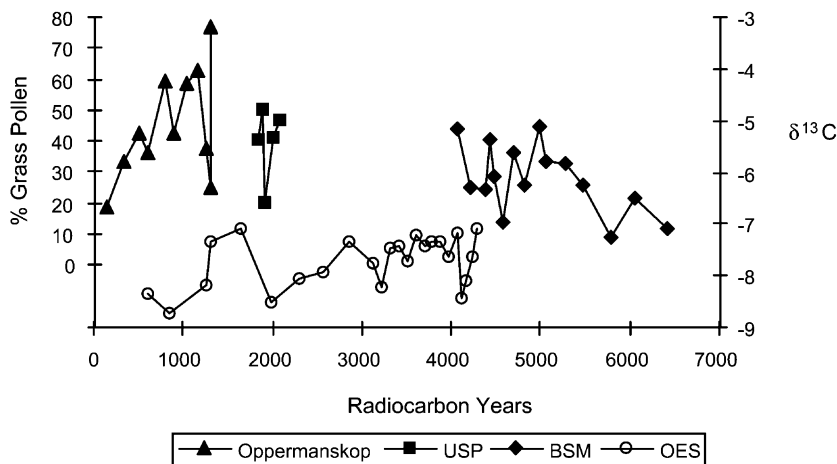


Fig. 22. Percent of grass in pollen samples from Oppermanskop and Meerkat hyrax dung middens, BSM, and USP compared to Ostrich eggshell $\delta^{13}\text{C}$ values (Scott et al., 2005).

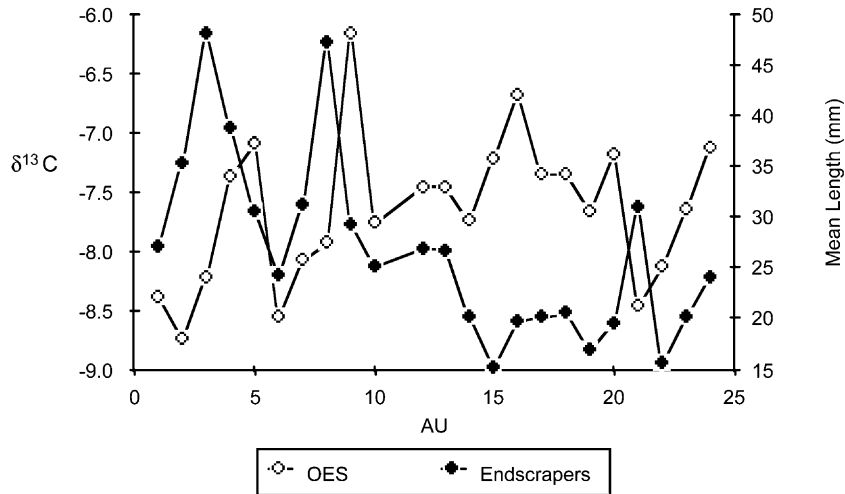


Fig. 23. Ostrich eggshell $\delta^{13}\text{C}$ curve and end scraper mean lengths for individual analytical units (AU) at Blydefontein Rock Shelter.

mean end scraper length implies that short end scrapers are associated with dry conditions and longer end scrapers are found during wetter times. At two points on this scale (AU 6–7 and AU 22–24) the occurrence of freshwater crabs (*Potamonautes perlatus*) in the deposits is high, although not included in the mammalian fauna analysis. While I never ate freshwater crab, a Zeekoe Valley farm laborer told me they taste like mud. These two periods correspond to droughts and it seems apparent that during these periods human diet breath increased to include much less palatable foods such as freshwater crabs, and concurrently scrapers were resharpened more intensively.

Discussion

Artifact analysis from Blydefontein Rock Shelter as well as the examination of regional radiocarbon dates and the Zeekoe Valley survey data (Deacon, 1974, 1984; Mitchell, 2002; Sampson, 1985) indicate that during drought periods LSA hunter–gatherer societies in the Interior Plateau show evidence of greater mobility, larger territories, and lower population densities. At the same time technological strategies shifted. End scrapers were utilized more intensively and there appears to have been a desire to keep maintenance tools in working condition for longer periods perhaps during more intensive and dedicated work sessions. Also complete backed microlithic tools were discarded more frequently to keep armaments at a higher level of readiness to insure hunting success. This appears to be a response to high-risk conditions in terms of higher failure-to-procure costs.

Conversely, evidence from the Blydefontein Rock Shelter and the Zeekoe Valley suggests that LSA

Table 8

Basic strategies and technological, environmental, and economic patterns reflected at Blydefontein Rock Shelter

Low risk strategy (time-minimization)	High risk strategy (resource-maximization)
Wetter conditions	Drier conditions
Larger animals	Smaller animals
Less end scraper resharpening	More end scraper resharpening
More local raw materials	More nonlocal raw materials
Fewer complete discarded backed microliths	More complete discarded backed microliths

hunter–gatherer populations increased, territories shrunk, and mobility declined during wetter conditions. Along with these shifts, evidence from Blydefontein suggests that end scrapers were used and resharpened less intensively, and broken microlithic tools were discarded more frequently (Table 8). All hunter–gatherers who occupied Blydefontein Rock Shelter would probably fit Binford's (1980) definition of foragers, but the technological strategies of these groups reflect a range of choices and subtle shifts in strategies.

Analysis of ethnographic data (Bousman, 1993) suggests that collector-like technological strategies favor intensive repair of maintenance tools and replacement of extractive tools if there is a potential for weapon failure. Other analyses of economic risk (Bamforth and Bleed, 1997; Torrence, 1989) can be used to suggest that this strategy would be more common during periods when the costs of economic risk (i.e., the severity of shortfalls) are high. Forager-like strategies favor expedient use of maintenance tools, the intensive curation through repair of extractive tools, and discard after failure or exhaustion. This second strategy would be more likely when the costs

of economic risk are less severe, even if the probability of failing-to-procure foods was high. If collector-like technological strategies are employed by Blydefontein LSA hunter-gatherers during higher risk conditions with greater economic uncertainty brought on by drought conditions and forager-like strategies are used during circumstances of greater resource availability or predictability during moist periods, then these models provide a reasonable explanation for some, but not all, of the technological shifts that characterize the variability in the LSA record as preserved at Blydefontein Rock Shelter.

Ethnographic studies in the Kalahari indicate that San groups employ both collector-like and forager-like exploitation strategies. For example the G/wi in the extremely dry Central Kalahari conduct biltong (jerky) hunts composed of logistically organized task groups for the express purpose of accumulating meat in bulk (Silberbauer, 1981). The !Kung do not use bulk hunting strategies in the resource-rich and wetter Dobe area (Lee, 1979). Although rarely considered in optimal foraging models, Wiessner (1977, pp. 62–63) suggests that men and women integrate their gender-based subsistence strategies in a flexible manner. When women were unable to collect a reasonable amount of plant foods during a drought, !Kung men shifted from hunting antelope to trapping small animals. Antelopes are a highly valued but unpredictable food source, particularly during a drought, while trapping small animals provides a much more reliable source of food. This expanded the group's overall diet breadth, shifted the men's strategy from risk-prone to risk-adverse, and helped maintain the group's overall food intake.

The hunter-gatherers who occupied Blydefontein Rock Shelter also appear to have employed efficient technologies when needed as tool designs in projectile armatures changed. This appears to be related to the expedient production of blanks for straight-backed bladelets and cannot be related to environmental shifts or to presumed changes in economic risk. The reasons for changes in projectile armature design are not clear, however. In the Interior Plateau, the use of bone points, presumably with poison at least during the late prehistoric and protohistoric Smithfield, may be linked to hunting larger animals, and the use of microliths may be associated with hunting or even trapping of smaller animals. However, H. Deacon (1972) suggests the reverse pattern applies at sites near the coast. Certainly, poison would be unnecessary for the killing of small game. It is probably not this simple, but Dunn (1880) does say that Bushmen used poison on arrows intended for killing large animals, but not on arrows used for killing small game. The shifts in backed microlith design are more obtuse. These may be stylistic changes (Wadley, 1989), but more research will be necessary before these shifts can be fully understood. Mitchell (2000) documents many of these same patterns in the Caledon Valley and the Phuthiatsana-ea-Thaba-Bosiu

basin of the eastern Free State and western Lesotho and shows that these patterns occur over a larger region.

These data suggest that LSA hunter-gatherers had a remarkably flexible approach to their technology, mobility and economic exploitation, and that their strategies were sensitive to the environmental fluctuations that influenced food availability. That this sensitivity existed, at least in the protohistoric period, is amply reflected in the myths and stories of the 19th century northern Cape /Xam Bushmen (Bleek and Lloyd, 1911; Bleek, 1935; Lewis-Williams, 1981, 2001). These stories leave little doubt that the Bushmen knew all about the economic risks caused by environmental variability, and the often-experienced impact can be told best in their own words:

Bushmen do not kill frogs, because the rain does not fall if we kill frogs. A drought comes if we have killed frogs, and the rain does not fall, and the place becomes dry.

Then it is that the Bushmen grown lean, because the rain does not fall, and the springbok are not there, and the locusts are not there. Then the locusts vanish, the springbok also vanish. The Bushmen eat gambro (a sort of melon), the plants of which are there. The (other ?) plants vanish, only the gambro is there.

Drought is that which makes the country grow white, the bushes dry up in the drought. When the rain falls like this (a Cape Town winter), food will be plentiful, then people say, the rain falls bringing plenty, and people are not careful of the locusts and the springbok.

Dictated by *!Han ≠kass'o* a Bushman from the Strandberg (Bleek, 1935, pp. 301–302).

Conclusions

Among Bushmen, the association of greater economic risks during drier conditions with collector-like hunting and technological strategies, and lower risks during wetter conditions with forager-like strategies is evident in the South Africa ethnographic and archaeological records. In addition, as the above story by *!Han ≠kass'o* hints, during periods with more resources, economic success does not place such stringent requirements on the Bushmen's food getting strategies. These results suggest that greater economic risks in terms of cost-of-loss occur during drier conditions because of reduced prey densities, and the resultant shortfalls forced Bushmen to shift to broader diets. These shifts were made possible, or at least more successful, by utilizing more costly technological strategies such as greater repair of maintenance tools and more rapid replacement of extractive tools. The ethnographic and archaeological analyses demonstrate that technological strategies of prehistoric and historic San changed, in subtle ways, in response to environmental fluctuations

and accompanying shifts in diet breath. These shifts occurred over very short durations and are the result of microscale technological adjustments that increased the ultimate success of the group.

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