CHAPTER 7
ALM ROCKSHELTER LITHIC DEBITAGE ANALYSIS: IMPLICATIONS FOR HUNTER-GATHERER MOBILITY STRATEGIES IN THE BIG HORN MOUNTAINS, WYOMING

BY BRIAN E. OSTAHOWSKI AND ROBERT L. KELLY

ABSTRACT
Alm rockshelter is a prehistoric site located at the mouth of Paintrock Canyon, on the western side of the Big Horn Mountains. The site contains a well-stratified record of occupation from late Paleoindian to late Prehistoric times. This study analyzed lithic debitage excavated at Alm rockshelter’s three test units to test implications of the hypothesis that the Big Horn Basin region experienced population growth and decline during certain time intervals which correlate with decreasing and increasing aridity (Kelly et al 2013). Debitage analysis tests the hypotheses that (a) when the region experienced an increased population (associated with cooler/wetter climate), the prehistoric population used Alm rockshelter through residential mobility; and (b) at times of decreased population (drier/warmer climate), people used the shelter through logistical mobility.

This much we know: mobility is a key attribute of the foraging adaptation. All foragers use a mix of residential mobility to bring consumers to resources, and logistical mobility to bring resources to consumers. Different mobility strategies among foraging societies result from a heavier reliance on one of these over the other. In this paper, we are concerned with detecting changes in mobility from lithic assemblages, specifically from debitage, and with how mobility is linked to climatically-induced resource changes and human population density.

Our case study comes from the site of Alm Shelter, located on the western edge of the Big Horn Mountains, in northwestern Wyoming. Diachronic changes in hunter-gatherer mobility are reconstructed through an attribute analysis of the site’s debitage assemblage. This focuses on patterns of core reduction, stone tool production and curation, the ratio of local to nonlocal toolstone, debitage density, and formal chipped and groundstone tools. We conclude that changes in prehistoric population density combined with climate changes helped govern settlement organization for hunter-gatherers who used Alm Shelter.

POTENTIAL PITFALLS OF DEBITAGE ANALYSIS
Inferring types of mobility rests on the assumption that debitage types and attributes are indicative of the types of tools produced and reduction strategies used at a location (Andrefsky 1998; Sullivan 2001). This seems a safe assumption since debitage tends to remain where it was produced; some flakes may be scavenged by a site’s later occupants and flakes may be swept up and discarded away from where they were produced, but by and large evidence of tool production and maintenance remains where it was produced. Unlike retouched stone tools, debitage is also generally abundant in even small samples of a site, such as are obtained through test excavations (which is the case here), and hence amenable to statistical analysis.

Residential sites typically have high tool diversity and consequently should contain debitage associated with both formal and informal tool production (Andrefsky 1998; Chatters 1987). Accordingly, debitage associated with the initial stages of tool manufacture, such as core reduction, would be commonly expected. Likewise, we would also expect to find a high frequency of local lithic materials engaged in initial core reduction because local toolstone transport costs would be minimal (Beck 2008; Metcalf and Barlow 1992).

Logistical sites should exhibit debitage suggestive of low tool diversity. Multifunctional tools, such as a biface,
are often used on logistical forays because they are portable and can perform different roles depending on the conditions imposed by the length and purpose of the foray as well as by raw-material distributions (Andrefsky 1998; Kelly 1988; Kuhn 1994). In general, the debitage generated on a logistical foray should reflect the rejuvenation and maintenance of multifunctional tools rather than their production (Andrefsky 1998). This means that we should expect to find a higher ratio of nonlocal toolstone in assemblages generated by logistical movements (Kuhn 1994; Surovell 2009), and evidence of biface reduction. Local toolstone reduction should be confined to early stages of reduction and expedient flake tool production.

Unfortunately, debitage can be quite frustrating to analyze. This is largely a product of the fact that debitage has no “natural” categories other than raw material (and heterogeneity in sources can make source assignments difficult). Zooarchaologists can divide bone into species and elements, and be fairly confident in their assignments because species and skeletal elements do not grade into one another; there is no gray area between a bison and a mouse, or between a femur and a rib. There are unidentifiable bones, but by and large analysts can agree on species and element of those that are identifiable. However, many debitage characteristics, e.g., platform type, dorsal scar count, or even termination type are not measured or categorized in the same fashion by different analysts, even highly experienced ones (Dukeman 2002). And the more fine-grained the categories (e.g., measuring cortex in bins that increase by 10%), the more likely analysts are to disagree. In this paper we use debitage attributes that we think are the most reliably recorded and hence the most replicable among analysts. This limits us to fairly coarse categories.

MOBILITY, RESOURCE DEPRESSION AND POPULATION

Changes in the form of mobility practiced should reflect the combined effect of human population density, climatically-induced changes in food density, and the distribution of key non-food resources such as shelter, water, and firewood (Kelly 2013). Larger human populations and/or climate changes can lead to resource depression of high-ranked food resources, especially large game (Wolverton 2001; Bryan 2006). In general, a reduction in high-ranked resources will lead to greater residential mobility. High-ranked resources are high-ranked precisely because they provide high post-encounter return rates. Resources that provide high post-encounter return rates can be exploited at greater distances from a camp, hence encouraging logistical acquisition of those resources. If high-ranked resources become less common, optimal foraging theory leads us to expect diet to expand, and include more low-ranked (i.e., low return-rate) foods (Kelly 2013). Low ranked foods cannot be acquired at an energetic gain very far from camp, requiring that people use residential mobility to move consumers closer to food.

In an arid environment, we expect drier conditions to reduce the availability of food on the landscape through a reduction in primary production. Although all food types could be depressed, a reduction in the abundance of large game should result in a dietary expansion under dry conditions. This will be exacerbated under conditions of high population density. Under moister conditions, we expect diet to contract, focusing more on large game. Accordingly, residential mobility should decrease and logistical mobility increase among pedestrian foragers.

However, arid conditions will also limit the availability of water, and that fact could counteract a desire to move residually. We return to this fact below. We use the summed probability of calibrated and radiocarbon dates (see Kelly et al 2013) as a proxy measure of population. These dates come from a database of 158 dates from closed sites (caves and rockshelters, including Alm Shelter), and 421 dates from open-air sites in the Bighorn Basin and surrounding mountains. Summed probabilities were generated using CALPAL (Hulu 2007) separately for open-air and closed sites. The open-air site distribution was taphonomically-corrected (see Surovell et al 2009) and averaged with the closed site distribution.
Figure 7.1 shows the changes that have occurred since human populations entered the region about 13,000 years ago (all ages in calibrated years BP). Population grew to a peak at about 10,700 BP, then declined before it grew again, reaching a second peak about 9000 BP before declining dramatically. This 9000 BP peak, however, only appears in the closed site distribution; the open site distribution alone (not shown) declines continuously from 10,700 BP.

Population remains low throughout the early Holocene before it begins to grow ~7000 BP, reaching a peak ~4400 BP. Population then again declines rapidly, rises and falls, and then grows rapidly ~2000 BP, reaching a peak ~1100 BP. Population then again declines. We suspect that this final decline only partially reflects a decline in human population; it could also reflect a bias against dating the latest archaeological manifestation in a site (e.g., the uppermost hearth in a profile) and/or, for the very final portion of the sequence, the use of European artifacts to date contact-era sites and strata. (It may also reflect a decline in population, but one produced by introduced disease, rather than climate-linked declines in foraging.)

These periods of population growth and decline are closely tied to regional changes in temperature and moisture. Moisture is reconstructed from dated changes in elevations of Lake of the Woods, a high elevation lake in the northern Wind River Mountains (Shuman et al 2009); temperature is reconstructed from pollen spectra from cores taken from bogs in Yellowstone Park and the Bighorn Mountains (Shuman 2012); these data are portrayed in Figure 7.1. There is a tight and expectable relationship between the summed probability distribution and temperature and moisture: as climate becomes cooler and wetter, population grows, and as climate becomes warmer and drier, population declines (Kelly et al 2013). Moisture appears to be a stronger immediate factor in population change (expected in an arid environment) while temperature produces a consistent ~300 year lag in human population growth response. In addition, the human growth rate implied by the radiocarbon data is only 0.3%, lower than measured rates among ethnographically known foragers (Kelly 2013). This chapter investigates the relationship between mobility as measured bydebitage attributes, human population and climate change.
LITHICS IN THE WEST

ALM SHELTER

Alm rockshelter (48BH3457) is a well-stratified rockshelter located at 5150 ft asl (1570 m) at the mouth of Paint Rock Canyon in the foothills on the west side of the Big Horn Mountains (Figure 7.2). The site lies at the base of a predominantly limestone south-facing cliff and overlooks Paint Rock Creek less than 100 m to the south. The site area is defined by a cluster of large boulders to the east and a large talus cone to the south; the dripline encompasses an area up to 60 m but only about 5 m deep at most (Figure 7.3). Although many shelters are too small to be used by a large logistical party, let alone a residential group (even a single family), Alm is large enough to have easily accommodated the 18-28 people who commonly form a co-residing foraging group (Kelly 2013).

Kelly excavated a total of three 1 x 1 m test units during 2005 and 2009 field seasons. The site's excavated deposits are over 2 m deep (bedrock was not reached), cover the past 13,000 calendar years, are remarkably free of rodent disturbance, and are well-stratified and well-dated. Alm also contains a high density of archaeological materials. A total of 18,289 artifacts were recovered during excavations; this included 18,108 pieces ofdebitage, 45 projectile points/knives, 43 other bifaces, 61 retouched flakes, 20 scrapers and 12 manos. The sediments in the three test units are dated by 25 radiocarbon dates (Table 7.1). There were two minor reversals in test unit 1, and one major reversal at the base of test unit 3; the last of these was redated and all three reversals are ignored here. Levels without dates were assigned ages by interpolating from bracketing dates.

The Big Horn Basin is an arid intermontane basin of sparse grassland flanked to the east by the Big Horn Mountains (Francis 1997; Frison 2007a) which range from 4150 – 13,200 ft asl (1267-4018 m) (Francis 1997). Higher elevations become incrementally colder and wetter as the altitude increases while the basin floors are generally hot and dry (Young et al. 2000: 10). Alm...
LITHICS IN THE WEST

rockshelter is located at the confluence of desert-basin, grassland, and foothill-scrub zones as well as stream bank plant communities. Sitting on Paint Rock Creek, the site has a source of water that runs in even the driest of recent years; and the canyon it runs through provides access to the highest reaches of the mountains.

Prehistorically, the Big Horn Mountains supported significant animal populations, including Bighorn sheep, mule deer, white-tail deer, Rocky Mountain elk, antelope and bear (Frison 1978; Larson 1990; Walker 2007).

Herbivore populations in the Big Horn Mountains typically follow flora seasons and move from low-elevation summer to high-elevation winter feeding areas (Frison 1978; Hughes 2003). On the basin floors, archaeological evidence suggests that bison (Bison sp.) were supported on the open plains valley floors at different times (Frison 1992:331).

In general, the artifact assemblages recovered from rockshelters in the Bighorn Mountains suggest that the shelters were largely used as short term waystations for logistical hunting forays (Freeland 2012). These shelters typically contain very low densities of archaeological material, few hearths containing very little evidence of the use of economically-significant plants, very few groundstone artifacts, and numbers of projectile points (unpublished data). Alm shelter is somewhat different from other shelters investigated in the Bighorn Mountains, having a low lithic assemblage diversity, suggesting redundant use over time, a higher frequency of shatter and cortical flakes, suggesting early stage lithic processing, and yet a higher frequency of flakes with >3 scars on the dorsal surface (suggesting later stage reduction). Its hearths also contain a higher ratio of economic to fuel wood in the hearths, suggesting plant collection (Freeland 2012). Alm Shelter is therefore not typical of Bighorn shelters, but its location (at the mouth of a well-watered canyon) and size (large) means that it

Figure 7.3. Alm Shelter site topographic map showing location of three test units.
could have seen more use as a residential location than could other, smaller shelters located in less well-traveled corridors.

ENVIRONMENTAL CHANGE AND PREHISTORIC POPULATION EXPECTATIONS

The Holocene marks a transition to a post-glacial epoch in which warming climatic conditions caused adjustments in plant and animal distributions across North America. In the Big Horn Mountains paleoecological responses to aridity, temperature, moisture and summer/winter insolation changes moved coniferous taxa up and down in elevation along moisture gradients. This caused a dynamic resource distribution throughout the Holocene which affected prehistoric subsistence strategies and forced hunter-gatherers to carefully monitor plant and animal resources.

In the Big Horn basin, the early Holocene transition, around 12,000 BP, exhibited a continuingly warming climate (Brooks 1995; Frison 1992). Mesic habitats in the basin were stressed by increased seasonal extremes (Larson 1990:26). Nonetheless, bison, which feed on mesic grasses and sagebrush biomass, proliferated in the region until about 9,000 BP, at which point they decrease in frequency in the archaeological record (Hughes 2003; Larson 1990). Frison (1992; 2007a) argues that during the earliest Holocene, evidence of meat caches and

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Table 7.1. Radiocarbon dates from Alm Shelter.

<table>
<thead>
<tr>
<th>Lab Number</th>
<th>Material</th>
<th>14C Age</th>
<th>Calibrated</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA-68840</td>
<td>Carbon, hearth (Juniperus)</td>
<td>1178±36</td>
<td>1110±60</td>
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<td>AA-68837</td>
<td>Carbon, hearth (Populus)</td>
<td>1610±42</td>
<td>1500±50</td>
<td>Test 1, level 3, profile</td>
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<tr>
<td>AA-72381</td>
<td>Carbon</td>
<td>1380±40</td>
<td>1320±30</td>
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<tr>
<td>AA-72380</td>
<td>Carbon</td>
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<td>3060±90</td>
<td>Test 1, level 5, profile, processed by J. Finley</td>
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<tr>
<td>AA-68641</td>
<td>Carbon, hearth (Populus)</td>
<td>4768±71</td>
<td>5480±100</td>
<td>Test 1, level 6/7</td>
</tr>
<tr>
<td>AA-68642</td>
<td>Carbon (Populus)</td>
<td>6746±40</td>
<td>7610±40</td>
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</tr>
<tr>
<td>AA-72379</td>
<td>Carbon</td>
<td>6700±50</td>
<td>7570±50</td>
<td>Test 1, level 10, profile, processed by J. Finley</td>
</tr>
<tr>
<td>AA-72377</td>
<td>Carbon</td>
<td>8240±60</td>
<td>9220±90</td>
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<tr>
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<td>9260±100</td>
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<td>12970±80</td>
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<tr>
<td>PRI-09-158-BH3457-709</td>
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<td>870±50</td>
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<td>PRI-09-158-BH3457-713</td>
<td>Carbon (Salicaceae)</td>
<td>3985±20</td>
<td>4470±40</td>
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<td>Carbon (Picea)</td>
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<td>uncharred twig (Poaceae)</td>
<td>2425±15</td>
<td>2430±40</td>
<td>Test 3, level 3, profile</td>
</tr>
<tr>
<td>PRI-10-149-673</td>
<td>carbon (betula)</td>
<td>4405±15</td>
<td>4980±50</td>
<td>Test 3, level 7, profile</td>
</tr>
<tr>
<td>PRI-10-52-672</td>
<td>Carbon (Salicaceae)</td>
<td>5700±15</td>
<td>6480±20</td>
<td>Test 3, level 9, profile</td>
</tr>
<tr>
<td>PRI-10-149-686</td>
<td>Carbon (Salicaceae)</td>
<td>8710±25</td>
<td>9660±60</td>
<td>Test 3, level 13, profile</td>
</tr>
<tr>
<td>PRI-09-158-BH3457-714</td>
<td>carbon (betula)</td>
<td>6245±20</td>
<td>7210±40</td>
<td>Test 3, level 20, excavated; out of sequence</td>
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<tr>
<td>PRI-10-52-682</td>
<td>Carbon (Salicaceae)</td>
<td>10975±25</td>
<td>12860±60</td>
<td>Test 3, level 20, profile</td>
</tr>
</tbody>
</table>
structures on the valley floor suggests that the foothill-mountain margins were used by the people living on the valley floor, such as Clovis or Folsom groups, through logistical foraging and lithic procurement. By about 12,000 BP, a separate Paleoindian occupation of the Big Horn Mountains occurred, the Foothill/Mountain Complex (Frison 1992; Kornfeld et al 2010). It is evidenced at several closed sites such as Mummy Cave, Medicine Lodge Creek, Two Moon Shelter, and Little Canyon Creek Cave. Researchers believe that this complex represents a parallel but different settlement and subsistence system from that of the open plains and valleys (Kornfeld et al 2010:95).

The continuing warm and dry climate of the early Holocene, between 10,000 and 6000 BP restricted the forests to higher elevations, and people shifted their subsistence emphasis toward seasonally migratory big-game species in the mountains (Hughes 2003:280). As a result, closed sites along the western foothills of the Big Horn Mountains experienced increased use (Frison 1978); this is seen in the 9000 BP peak in the closed site radiocarbon date distribution mentioned above. The 9000 BP peak, however, was short-lived and suggests that people may have retreated to the mountains as climate became more arid, but that eventually the human population of the mountains declined as well.

The climate data suggest a gradual return to mesic conditions during the mid-Holocene, from 7000 to 4000 BP; human population grew at this time. Bison reappeared in the High Plains as evidenced by the return of communal bison hunting (Hughes 2003). However, aridity returned soon after 4200 BP, and may have been presaged by extremely severe droughts about 4200 BP that were felt across the northern hemisphere (Booth et al 2005; Frison 1978; Reeves 1973). By about 3000 BP the climate in the Rocky Mountain region exhibited climate conditions similar to today (Shuman et al. 2009:1861).

Wetter conditions returned by 2000 BP, and forest zones slowly descended downslope and the mountains’ carrying capacity increased. The prehistoric human population grew, reaching a peak around 1100 BP. This peak was short-lived as climate returned to more xeric conditions during the Medieval Climate Warming.

PREDICTIONS

As outlined above, under dry conditions we expect human populations to use the better-watered portions of the landscape, and to increase residential mobility in response to lower overall return rates. This could produce two conflicting demands: water, which might restrict people, and low return rates, which would encourage moving consumers to resources. Water, in fact, dictates mobility under extremely arid conditions. The Ju/'hoansi, for example, limit residential mobility during the dry season, preferring to place themselves on water pans and forage further afield. The neighboring G/wi, on the other hand, lack such pans of water and so increase their residential mobility during the summer, acquiring water from melons and the body cavities of hunted game. Likewise, in Australia’s western desert and in Baja California, foragers generally remain on a waterhole until it has completely dried, accepting low daily return rates produced by longer forays for low return rate foods (Kelly 2013). Where the regional landscape is dry but where water sources are available as linear streams, we might expect people to move more frequently, albeit constrained along streams.

At the same time, high population density will reduce the availability of high-ranked resources, resulting in an expansion of diet, the need to move more frequently, but also in constraints on a group’s ability to move (Kelly 2013). Thus, high human population densities could have the same effect as an arid climate. Such changes could result in technological innovations (e.g., plant-processing technologies) that then permanently alter the perceived return rates of available foods. We use Alm Shelter to explore the contributions of climate and human population size on mobility in northwestern Wyoming.
METHODS AND ASSUMPTIONS

The debitage analysis was conducted within the 10 cm arbitrary levels used in excavation. Analysis was restricted to those specimens that did not pass through a ¼” screen. In total, 5216 pieces of debitage were analyzed (28.8% sample); 92% of this assemblage is one form of chert or another. A suite of metric and non-metric traits were recorded on each specimen (Table 7.2). The recording of certain lithic debitage attributes reflects the results of replicability studies of lithic attributes. For example, Dukeman (2002) showed that two measurements in particular, dorsal flake scar count and platform facet count, are not counted similarly by analysts. Consequently, these attributes were recorded in broad ordinal categories. Similarly, dorsal cortex is recorded simply as present/absent.

LITHIC RESOURCE DISTRIBUTION

The Permian age Phosphoria Formation is the dominant toolstone in the Alm assemblage (n=2359, 45%) and is a high quality chert exposed widely along the slopes of the foothills (Frison 2007b). Phosphoria veins are exposed at various thicknesses which often exhibit a variety of colors within exposures (Campbell 1956).

Phosphoria is similar to the high-quality Pennsylvanian age Amsden Formation (n=8; 0.15%), which is exposed at a slightly higher elevation.

At the lowest elevations in the Big Horn Mountains, along the basin margin, runs a ban of Upper Jurassic Morrison formation which produces high quality fine-grained quartzites and cherts (Frison 2007b). Morrison outcrops are typically exposed as veins in and around highly eroded gullies which are littered with Cloverly Formation boulders (Jennings 2005:52). Morrison debitage is considered to be procured locally (~10 km) and is the second most abundant material at Alm (n=279, 5.3%).

The Mississippian age Madison Formation produces an exceptionally high-quality chert (Francis 1997:219). Madison cherts are heterogeneous but have a few distinctive colors. Madison cherts are rare (n= 140, 1.9%) and represent a high elevation, nonlocal prehistoric toolstone identified at Alm rockshelter. As with Medicine Lodge Creek, the source of Madison toolstone is likely the Spanish Point Quarry, located some 20 km from Alm Rockshelter (Frison 2007b:30) and about 1200 m higher in elevation (Ostahowski 2011).

Quartzite occurs as secondary gravel deposits along the interior of the basin (Francis 1997) and is rare at Alm.

<table>
<thead>
<tr>
<th>Ratio Scale</th>
<th>Ordinal Scale</th>
<th>Non-Metric/Nominal Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (nearest .01 mm)</td>
<td>Dorsal Flake Scar (&gt;3)</td>
<td>Raw Material Type</td>
</tr>
<tr>
<td>Width (nearest .01 mm)</td>
<td>Flake Striking Platform Count (&gt;3)</td>
<td>Flake Portion and Artifact Type</td>
</tr>
<tr>
<td>Thickness (nearest .01 mm)</td>
<td>--</td>
<td>Presence of Cortex</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>--</td>
<td>Presence of Thermal Alteration</td>
</tr>
<tr>
<td>Interior Platform Angle (°)</td>
<td>--</td>
<td>Presence of Feather Termination</td>
</tr>
<tr>
<td>Platform Characteristics (Presence/Absence)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Whole Platform</td>
<td>Cortical Platform</td>
<td>Lipped Platform</td>
</tr>
<tr>
<td>Split Platform</td>
<td>Platform Plain</td>
<td>Platform Abrasion</td>
</tr>
<tr>
<td>Crushed Platform</td>
<td>Dihedral Platform</td>
<td>Sheared Bulb of Percussion</td>
</tr>
</tbody>
</table>
LITHICS IN THE WEST

Exotic materials such as basalt (n=11, 0.2%), obsidian (n=11, 0.2%) and clear quartz (n=22, 0.4%) are nonlocal and extremely rare at Alm. Shale (n=1, 0.01%), silicified shale (n=42, 0.8%), and silicified siltstone (n=2, 0.01%) appear in low frequencies and are considered local, due to the variety of lithologies in the Phosphoria formation (Campbell 1956).

Noting that 20 km (one-way) foraging trips are rarely documented in the ethnographic literature, Surovell (2009:78) defines local raw material as anything within a 20 km radius of a site, and non-local material as anything found further away. This definition means that all Phosphoria and Morrison quartzite is considered local toolstone. Since there is variation within Phosphoria, we considered all cherts to be locally procured unless identified to a type found more than 20 kms from the site (i.e., Madison).

RESULTS

The simplest attribute of adebitage assemblage is abundance. We measure abundance here in terms of density within 10 cm excavation levels as:

\[
\text{Debitage density} = \frac{\text{Total weight of sediment excavated in level}}{\text{Weight after screening}}
\]

This measure controls for differences in the actual thicknesses of levels and for that portion of a level’s volume which is rock. Since debitage cannot occur inside rock (that enters the site as rooffall or colluvium), this method measures debitage density relative to the portion of the level’s volume that could contain debitage. We then created a concordance of levels for all three units using radiocarbon and interpolated dates (Table 7.3), assigned a mean date to each set of levels, and calculated the mean debitage density by level. To check ourselves, we calculated debitage density in several other ways, including looking at cumulative weight, with similar results.

We initially expected debitage density to parallel the 14C frequencies that monitor regional population density. However, we found the opposite pattern (Figure 7.4A): although population density is low in the early Holocene, and high in the late Holocene, debitage density is highest at Alm in the early Holocene and lowest in the late Holocene. This does not appear to be an artifact of changes in sedimentation rates, which remain relatively constant. Assuming that debitage density measures the intensity of shelter use, then Alm is used more intensively at times of low as opposed to high population density. Since population density responds to climate (Kelly et al 2013), we can go further and state that Alm is used when population density is low and the regional climate is more arid. In fact, debitage density is correlated with temperature and moisture (from Kelly et al 2013; r=0.70, n=20 pairs, p=0.003; Figure 7.4B). It makes sense that the regional population might decline as climate becomes more arid (and foraging return rates decline). It also makes sense that during arid times well-watered places, such as Paint Rock Canyon, might see more use. While 25 dates are not sufficient to create a radiocarbon frequency comparable to the regional one, Alm does contain spikes of summed probability values in the early Holocene (at 9700, 9000, 7600, and 6500 BP), when the regional record suggests depopulation (other dateable hearths lie stratigraphically between those which produced these spikes so these dates are not isolated occurrences).

Attribute Trends across Lithic Materials

The distribution of debitage attributes are compared among Phosphoria toolstone, Madison toolstone and Morrison toolstone to ascertain if raw materials were preferentially used for certain reduction activities. A series of chi-square tests (from Ostahowski 2011) found significant differences in the distributions of cortex (χ²=16.59, df=2, p<0.001), lipped platforms (χ²=6.89, df=2, p=0.031), platform abrasion (χ²=8.16, df=2, p=0.016), thermal alteration (χ²=15.41, df=2, p<0.001), whole platforms (χ²=6.45, df=2, p=0.039), platform cortex (χ²=12.14, df=2, p=0.002) and split platforms (χ²=9.31, df=2, p=0.009) across raw material types. However, there are no significant differences among the three raw material types in the presence of >3 dorsal scars on whole flakes (χ²=2.23, df=2, p=0.32), platforms
bearing >3 facets (χ²=1.19, df=2, p=0.55) and crushed platforms (χ²=1.26, df=2, p=0.53). There is also no difference in mean whole flake weight between raw materials (F=1.006, p=0.36).

The adjusted standardized residuals indicate that higher than expected frequencies of cortex, platform cortex, and thermal alteration, coupled with a lower than expected distribution of whole platforms suggests a general pattern of initial core reduction for Phosphoria at Alm throughout time (Table 7.4). Split platforms tend to be produced in high frequencies during core reduction and drive down the frequency of whole platforms (Prentiss 2001). Given Alm’s short toolstone transport distance to Phosphoria formation quarries (some stone is available within a kilometer of the site) it is not surprising that early stage Phosphoria reduction occurred at Alm.

The Madison formation debitage exhibited higher than expected frequencies of lipped and whole platforms. Lipped platforms are produced by bending fractures often associated with soft hammer percussion during later stage bifacial thinning and tool production (Andrefsky 1998; Cotterell and Kamminga 1987). Flakes removed during later bifacial reduction stages are expected to have obtuse interior platform angles (Sullivan and Rozen 1985:758). However, the mean Madison lipped platform angle (n=14) of 125° is no higher than the mean Phosphoria (125°, n=145) or the mean Morrison (125°, n=25). Nonetheless, other attributes of Madison debitage are not suggestive of initial core reduction. Morrison debitage attribute trends also indicate later stage reduction.
Figure 7.4. A. Relative human population size (14C summed probability values) plotted against debitage density at Alm Shelter and estimated sedimentation rate. B. Relationship between Alm Shelter debitage densities by chronological unit plotted against temperature and moisture estimates.
Table 7.4. Adjusted Standardized Residuals across Significant Attribute Distributions

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Phosphoria</th>
<th>Madison</th>
<th>Morrison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortex*</td>
<td>Higher (3.91)</td>
<td>--</td>
<td>Lower (-3.89)</td>
</tr>
<tr>
<td>Lipped Platforms</td>
<td>--</td>
<td>Higher (3.11)</td>
<td>--</td>
</tr>
<tr>
<td>Platform Abrasions</td>
<td>--</td>
<td>--</td>
<td>Lower (-3.81)</td>
</tr>
<tr>
<td>Thermal Alteration*</td>
<td>Higher (2.22)</td>
<td>Lower (-2.19)</td>
<td>Lower (-3.66)</td>
</tr>
<tr>
<td>Platform Cortex</td>
<td>Higher (2.29)</td>
<td>--</td>
<td>Lower (-4.04)</td>
</tr>
<tr>
<td>Platform Split</td>
<td>Higher (2.65)</td>
<td>--</td>
<td>Lower (-5.24)</td>
</tr>
<tr>
<td>Platform Whole</td>
<td>Lower (-2.50)</td>
<td>Higher (3.40)</td>
<td>Higher (3.37)</td>
</tr>
</tbody>
</table>

*Includes all flake portions in analysis

The most telling of the attributes is the low frequency of cortex, on both the dorsal surface and platforms. The higher than expected frequencies of complete flakes with whole platforms could be the result of edge shaping and platform preparation (Prentiss 2001). Thus, a pattern emerges which associates Phosphoria cherts with early stage reduction and Morrison and Madison with later stage reduction, although it is clear that no raw material was left at the site solely through only one portion of the reduction sequence.

**DIACHRONIC CHANGES IN ATTRIBUTES**

The earliest definitive evidence of a human use of Alm Shelter comes from a hearth near the base of unit 2 dated to 11,720 BP; another hearth in unit 1 dates to 10,950 BP. Still older dates (approximately 12,900 BP) lie deeper in all three units, but the associated archaeological material is sparse and small, and could be a result of downward movement of the later archaeological material. In fact, assemblages are very small at both the very early and the very late ends of the sequence at Alm; these small samples affect some of the data patterns and are generally ignored in analysis.

A number of the recordeddebitage variables show no significant changes or trends over time. This suggests that the shelter was generally used redundantly through time. However, some debitage variables do show significant changes over time, and the debitage density data suggest that the shelter’s use may have changed during the early Holocene when regional population was low and climate was quite arid, and during the latest Holocene, when regional population was at a peak, and climate was cooler and wetter (with the exception of the Medieval warming).

**Toolstone Source and Local Source Flake Size**

During the earliest period of the Holocene at Alm, local toolstone dominates the debitage assemblages (Figure 7.5A). This trend reverses ~4,000 BP, coincident with the beginnings of extreme aridity. Local toolstone again becomes increasingly important from ~7500 to 6000 BP, coinciding with population growth as climate ameliorates. The ratio of local to nonlocal toolstone declines again just before population peaks about 4500 BP, and remains low throughout the remainder of the sequence. Mean Phosphoria flake size is largely inversely related to the local:nonlocal ratio, although not significantly so (Figure 7.5A, B). Where non-local materials dominate, Phosphoria may occasionally be reduced expediently for flake tools, resulting in larger flakes. Where local materials dominate, Phosphoria could be reduced for flake tools, but also to manufacture and resharpen implements, resulting in greater variability in flake size (Figure 7.5B). The pattern that emerges is that prior to 10,000 BP, debitage assemblages are frequently dominated by local toolstone, represented by small flakes. Many of the later assemblages have high frequencies of nonlocal toolstone, with local sources more often represented by large flakes, but in lower frequencies.
Figure 7.5.  A. Relative human population size (14C summed probability values) plotted against average Complete Flake size of Phosphoria and the ratio of local to nonlocal debitage trends over time at Alm Shelter. B. The relationship between mean Phosphoria flake size and the local:nonlocal ratio of debitage.
Relative Thickness (RT)

High relative thickness (RT) values indicate a relatively thin flake produced by later stages in the reduction of bifaces (or resharpening) and low RT values indicate a relatively thick flake, produced early in the reduction sequence (Prasciunas 2007:343; Sullivan and Rozen 1985: Sullivan 2001). Figure 7.6 illustrates changes in RT values on complete flakes of high-altitude Madison toolstone, basin-floor Morrison toolstone, and local Phosphoria.

Although Phosphoria values change little over time, those for both Madison and Morrison toolstone exhibit a peak value ~10,800 BP. This indicates that on average, thin flakes from bifacial cores were discarded from nonlocal toolstone during the initial early Holocene. After this time, RT values decrease and, in general, maintain moderate values throughout the Holocene until around 1,200 BP, when frequencies of both nonlocal toolstone types decrease. At the same time peak RT values occur, there is a prevalence of flakes with >3 dorsal scars and flakes with >3 platform facets, both of which point to later stages in stone reduction. We associate these data with the transport of bifacial cores, of possibly all raw materials, to Alm. These data most likely point to logistical use of the shelter prior to 10,000 or 10,800 BP.

Local Toolstone Shatter and Crushed Platforms

As pieces of shatter are unlikely to be culled as usable tool blanks, it represents a variable that can monitor coarse-grained patterns of reduction. Low shatter weight points to the importing of local toolstone in complete or nearly complete form and is thus evidence of later tool production or resharpening. Crushed platforms can result from hard-hammer percussion early in the reduction sequence (Prentiss 2001), but also in later stages of reduction, e.g., during biface thinning, as a function of soft hammer destruction of the platform on

Figure 7.6. Relative human population size (14C summed probability values) plotted against changes in relative thickness values over time at Alm Shelter for Phosphoria, Madison and Morrison toolstone.
thin, fragile flakes. As Figure 7.7A illustrates, Phosphoria flakes exhibit high frequencies of crushed platforms ~9000-10,800 BP, low levels from 7500-9000 BP, and then high levels until ~1500 BP. Prior to 10,000 BP, high frequencies of crushed platforms are associated with small Phosphoria flakes and low shatter weight (Figure 7.7B), pointing to late stage reduction. By 9000 BP, Phosphoria shatter weight declines but is still high, and flake size is large, suggesting early core reduction. The frequency of crushed platforms, flake and shatter weight then all decline until ~7500-8000 BP. These data are difficult to interpret, but probably indicate a return to late stage reduction. From 8000 to 6000 BP, crushed platforms increase in frequency, and flake and shatter size both increase. These all suggest a return to early stage reduction.

In general, we associate low flake density and indicators of late stage reduction of toolstone (the prevalence of “thin” flakes of nonlocal toolstone, low flake and shatter weight) with logistical use of the site. Likewise, we associate highdebitage density and indicators of early stage reduction of toolstone (“thick” flakes of nonlocal toolstone, high flake and shatter weight) with more residential use of the site.

**Lithic Tools**
The retouched and groundstone tool assemblage is small (Table 7.5), as expected from a test of only three 1x1 m units; consequently, any interpretations are tentative. Because of the small sample size we collapse various tool categories: hunting equipment includes whole projectile points, fragments of points (bases, midsections and tips) and preforms. Bifaces include any other whole or broken bifacial implement that does not appear to be a projectile point. Scrapers and retouched flakes, which co-occur \( r = 0.68, n = 21, p = 0.0007 \), are combined as implements to work organic components of the technology. The category of manos includes broken and complete specimens.

Hunting equipment is positively associated with bifaces \( r = 0.67, n = 21, p = 0.0008 \), but not with scrapers/retouched flakes \( r = 0.23, n = 21, p = 0.30 \); Figure 7.8A and B). Manos appear ~7500 BP, and from that point on are correlated with hunting equipment \( r = 0.56, n = 11, p = 0.07 \); Figure 7.8A). The correlation of these two suggests that both hunting and plant processing were occurring at the same time whenever the shelter was used for the last 7500 years. This, in turn, suggests the presence of both men and women and thus residential use of the site.

The sample sizes here are so small that it is imprudent to draw detailed conclusions from artifact frequencies. Assuming that manos = plant collection/processing, then prior to 7500 BP the main subsistence task at the shelter was hunting, as evidenced by projectile points, though this probably came in spurts; points then decline in importance after 9000 BP. There is an increase in hunting about 6000 BP, and then not again, until ~850 BP. Scrapers appear to be inversely related to projectile points, and high frequencies could signal use of the shelter as a residence, where we might expect the manufacture of organic components of the technology to take place (along with hide-working, which the scrapers could also signal).

**DISCUSSION**
The debitage and tool patterns, along with the changes in demography and climate are summarized in Table 7.6. The shelter first appears to be used as a hunting camp for logistical parties, operating from residential bases elsewhere, given the evidence for biface maintenance and resharpennig. The presence of Morrison and Madison toolstone shows a use of both lower and higher elevation locations, but with local material dominant, the base camp was not far away. Climate is cool and wet, and human population density low. If the economy was heavily dependent on hunting, then logistical hunting in the mountains is expected. Given its location at the mouth of a well-watered canyon, Alm occupies prime foraging real estate, and could have been the site of residential occupations, but the lithic assemblage suggests otherwise.
Figure 7.7. A. Relative human population size (14C summed probability values) plotted against changes in Phosphoria mean complete flake size and the frequency of Phosphoria crushed platforms over time at Alm Shelter. B. Relative human population size (14C summed probability values) plotted against changes in mean Phosphoria shatter weight over time at Alm Shelter.
This use of the site may have continued until ~9000 BP, when retouched flakes and scrapers become common at the expense of hunting equipment, and nonlocal raw material becomes more common. The site’s use may have shifted back and forth between logistical and residential use: residential use at 9000 BP (although with a hunting focus) as regional population declined, but as people aggregated in the mountains and hence used the well-watered Paint Rock Canyon more intensively. With a further deterioration of climate and a concomitant reduction in people after 9000 BP, the site may have been used logistically until 8000 BP, but then returned to residential use about 7500 BP, this time with a growing focus on plants. This shift in economy and settlement pattern was not driven by population – as it appears to decline regionally and in the mountains – but by climate which became quite arid. As expected, hunting of high-ranked prey appears to decline in favor of lower-ranked plant collecting.

As climate become less arid, the human population grew from about 7000 to 4500 BP. Hunting equipment sees a brief resurgence about 6000 BP, but otherwise the site’s assemblage remains dominated by scrapers and retouched flakes, suggestive of residential use.
Figure 7.8.  A. Relative frequency of hunting equipment, bifaces, and manos over time at Alm Shelter. B. Relative frequency of hunting equipment and scrapers/retouched flakes over time at Alm Shelter.
### Table 7.6. Summary of Trends.

<table>
<thead>
<tr>
<th>Period</th>
<th>Debitage Density</th>
<th>Tools</th>
<th>Population</th>
<th>Climate</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-10,000 BP</td>
<td>Low</td>
<td>Milling equip.: non-existent</td>
<td>Very low, growing until 10,800 BP, then declines</td>
<td>Initially wet and cool, but becoming warmer</td>
<td>Logistical mobility, probably focused on large game hunting</td>
</tr>
<tr>
<td></td>
<td>Local material dominant</td>
<td>Scrappers most common, pre-9000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Morrison/Madison: “thin” flakes; crushed platform % high, flakes small, shatter small: Suggests late stage reduction/tool rejuvenation</td>
<td>Hunting equip most common, pre-10,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Debitage density low</td>
<td>Retouched flakes/scrappers replace hunting equipment</td>
<td>Initially low, but then grows, but only in mountains (shift from valley floor to foothills/mountains?), then declines rapidly, regionally very low, growth begins again about 7500 BP</td>
<td>Climate initially very warm and dry; cool, wet climate returns slowly beginning about 7500 BP</td>
<td>Initially logistical use; residential use ~9000 BP but with hunting focus</td>
</tr>
<tr>
<td></td>
<td>Nonlocal material dominant</td>
<td>Milling equipment appears about 7500 BP</td>
<td></td>
<td></td>
<td>return to logistical use, 9000-8000 BP</td>
</tr>
<tr>
<td>5000-10,000 BP</td>
<td>Initially late stage reduction of Phosphoria, but short-lived shift to early stage about 9000 BP, return to late stage 9000-8000 BP, and then early stage 8000-5000 BP</td>
<td></td>
<td></td>
<td></td>
<td>then residential, with focus on plants (hunting camp interlude ~5500)</td>
</tr>
<tr>
<td>0-5000 BP</td>
<td>Phosphoria flakes large</td>
<td>Milling equipment becomes more common (~1500 BP)</td>
<td>Regional population reaches peak 4500 BP, declines rapidly ~4200 BP</td>
<td>Climate becomes progressively cooler and wetter</td>
<td>Use of site declines, especially after 3000 BP; Site rarely used after 2000 BP</td>
</tr>
<tr>
<td></td>
<td>Debitage density declines, esp. after 3000 BP</td>
<td>Hunting equipment becomes more common</td>
<td>Population remains low, 4000-2000 BP, then begins to grow</td>
<td>Until, about 1000 BP with return to warmer, drier conditions (Medieval warming)</td>
<td>Mixture of residential use (plants) and logistical use (game)</td>
</tr>
<tr>
<td></td>
<td>Madison/Morrison: “thick” flakes (after 2000 BP)</td>
<td>Scrapers are non-existent</td>
<td>Reaches peak at ~1100 BP, then declines rapidly</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

That interpretation is supported by evidence of early stage tool production (an increase in mean local toolstone flake size, shatter size and the incidence of crushed platforms).

The debitage density suggests that the site’s overall use declined beginning about 6500 years ago. Climate ameliorates and population grows at this time, so it is unclear whether this is a function of climate, population or both. Debitage density makes a brief resurgence about 3200 BP. As this occurs right after a population collapse and a return to more arid conditions, we expect that it reflects the same phenomenon as the 9000 BP population peak and subsequent high levels of debitage density. The site’s use then continues its decline, as suggested by the declining debitage densities. The site sees little use after 2000 BP, when regional population is high; the prevalence of both hunting equipment and manos from 1500 to 850 BP may point to the site serving as a logistical hunting camp and/or as a residential camp with both hunting and plant collecting. This use of the site appears to correlate with a peak in prehistoric
human population, and hence may be driven more by population density than by climate.

CONCLUSION

We do not wish to push these data too far, derived as they are from three test units and small sample sizes. It is difficult to sort out the effects of climate and demography on hunter-gatherer settlement systems of this region of the past 12,000 years since climate and demography themselves are linked (Kelly et al. 2013), and since technological changes alter (more-or-less) forever the return rates of the available food resources.

Nonetheless, these data suggest that mobility strategies do indeed respond to the configurations of resources that change in response to climate and human demography (via humanly- or climatically-caused declines in the abundance of high-ranked resources). We can expect that a growing human population would have reduced the abundance of high-ranked game as climate returned to cool, moist conditions in the mid-Holocene. This, in turn, would have encouraged the greater use of plant foods, the development of grinding technology and use of Alm Shelter by residential groups who were moving consumers to resources. At the same time, we can see that under conditions of regionally low population densities in the early Holocene, an increase in aridity resulted in an aggregation of foragers in the mountains and an increased use of favored locales, such as Alm Shelter, and a shift from logistical to residential use of the site. This shift was driven more by climate than by human population density.

In conclusion, then, this analysis demonstrates that analyses of lithic assemblages can inform us about far more than reduction strategies. If we are able to link lithic reduction to the organization of foraging behavior, then lithic assemblages can help test hypotheses of how human foraging behavior changes in relation to population density and climate-induced changes in food resources.

REFERENCES CITED


