TECHNOLOGICAL ORGANIZATION
AND SETTLEMENT MOBILITY:
AN ETHNOGRAPHIC EXAMINATION

Michael Shott
Museum of Anthropology, University of Michigan, Ann Arbor, MI 48109

Functional requirements of activities do not alone explain variability in the technologies of forager groups. Rather, they are one among a larger set of factors that determine how technologies are organized within cultural systems. Failure to consider these other factors can impair interpretations of behavior based on analysis of artifact assemblages. One promising avenue of research is the relationship between technology and settlement mobility. Ethnographic evidence shows that elements of technology are related to the settlement mobility of forager societies. The implications of this relationship for archaeology are far-reaching, and they deserve careful consideration.

Stone tools comprise the most common class of archaeological remains of forager societies, and an elaborate array of analytical techniques and models has been developed for their study. However, the long history of stone tool analysis has not erased the doubts of many archaeologists about the prospects for inferring organization and behavior from lithic remains. On the contrary, fundamental limitations of archaeological lithic analysis are widely perceived.

In general, traditional analyses have sought to assign tools to discrete functional classes and to use the range of classes and relative frequency of tools in those classes as an index of activities conducted in past cultural systems (Bordes 1961). In such analyses, stone tools have been regarded as a static index of the economic organization of past societies, a way to determine what activities were conducted in those societies and in what characteristic frequencies.

In recent years, shortcomings in the traditional approach to stone tool analysis have been identified. The most important of these concerns the equation of formal or morphological tool classes with single, distinct functions. Terms familiar to all archaeologists, such as “projectile point” or “hide scraper,” imply that each formal tool class served a single unique purpose in a cultural system. This equation contains two premises: that morphology and function are coterminal and that each formal class possessed only a single function.

Both archaeological (Dibble 1984; Frison 1968; Semenov 1970; Wendorf 1968) and ethnographic (Gould 1978; Hayden 1977; Tindale 1965) studies have demonstrated that the simple equation of function and gross morphology in stone tools is not universally valid. In many cases, specific functional attributes of tools may be more important than gross morphology in determining the uses to which they are put (Parry 1983; White 1967). It is becoming apparent as well that some morphological tool classes often grouped under single functional headings may include tools used for a wide variety of purposes, effectively precluding their identification with a single function.
Traditional approaches to stone tool analysis fail to consider that the structure of assemblages is related not only to the set of activities in which they are directly employed, but also to other components of cultural systems. What is needed is an expanded view of the role of tool assemblages within cultural systems, one which takes account of how assemblages are adapted to constraints imposed by such aspects of cultural systems as their settlement mobility (Binford 1980; R. Kelly 1980, 1983), the maintenance of social boundaries (Wobst 1977), and properties of their resource species such as predictability, stability, and mobility (Torrence 1983). Once models are devised that systematically relate the structure of stone tool assemblages to such properties of the systems in which they are employed, it will be possible to use analyses of archaeological tool assemblages to infer these properties of wider anthropological interest. As Binford (1977a:35) notes:

No simple equation between tool and task, or frequency and popularity is possible. Before one can make meaningful statements as to the significance of patterns of observed variability in the archaeological record, he must consider the causal determinants of the patterning. Processes vary as organizations vary, forms of patterning vary as processes vary. Organizational variability is one of the major characteristics of cultural variation in general. Investigation of the organizational properties of systems and their processual consequences, archaeologically, is the first step toward an accurate attribution of meaning to observed patterning.

In order to address some of these processes and relationships, a preliminary model of technological organization is presented in the following section. This discussion is not confined to lithic technology, but applies to the complete array of materials and tool types used by selected foraging groups whose technology has been relatively well documented in ethnographic accounts. Obviously, understanding the role of stone tools and parts of tools within the complete technological inventory of foraging groups requires further research, and it is impossible at present to specify the set of conditions that governs the use of lithics versus other raw materials. Before this understanding can be achieved, however, archaeologists must learn more about variability in the general technology of foraging societies.

**TECHNOLOGICAL ORGANIZATION**

Tools are employed in the performance of tasks such as food procurement and the production of material goods. These uses may be termed task applications. Obviously, the functional requirements of these task applications impose significant constraints on the design of tools. Elements of design include tool size and weight, form, and specific functional attributes such as the profile and angle of stone tool working edges. Design of tools, however, can also
reflect other constraints in addition to those imposed by the specific purposes for which they are used. As Draper (1985:7) notes:

We would like to be able to recognize different activities performed at particular places . . . with varying cultural/behavioral repertoires. However, variability in lithic assemblages most likely is due to even more basic situational variability where the relevant variables are related to the tasks to be performed, the availability of suitable tools for those tasks, and the planning depth and repertoire or technical knowledge practised by the hominids involved.

The processes governing the structure of forager tool assemblages are complex. Traditionally, archaeologists have focused on only a single component of those processes: the functional task applications in which the tools are used. But other factors are involved as well. These include stylistic constraints as Wobst (1977, 1983) has shown. Importantly, they also can include requirements for the efficient use of time in task performance (Torrence 1983), minimization of risk (Wiessner 1982), and portability (Lee 1979).

An earlier examination of forager technological organization (Torrence 1983) utilized a large set of data compiled by Oswalt (1976) on the food procurement technology of numerous ethnographic groups. Oswalt’s data are drawn from groups occupying a wide variety of habitats (Oswalt 1976:10–12). The only criterion for inclusion was the existence of sufficiently detailed information on technology in ethnographic accounts. However, Oswalt’s study does not consider components of technology not directly related to food procurement. This is especially unfortunate for archaeologists, since maintenance tools often comprise the majority of archaeological assemblages (Hayden 1978). Furthermore, it frequently may be impossible to distinguish food procurement technology from other technological components, since the same tools and devices could be employed in both contexts. Nevertheless, Oswalt’s compendium offers a rare opportunity to examine the relationship between technology and the organizational components of foraging societies and can be used with its limitations in mind.

Ammerman and Feldman (1974) have provided the most comprehensive theoretical discussion to date on the relationship between technological organization and the archaeological assemblages produced by forager cultural systems. Their model includes both activities and distinct tool classes with functional significance. Importantly, it also considers (Ammerman and Feldman 1974:610, 611) the role of varying tool class use-lives (which they term drop rates and which are termed discard rates in subsequent discussion) and the mapping relations between tools and activities, by which they mean the functional relationships between tool classes and tasks. Ammerman and Feldman (1974:610) note the important role of activities in the generation of archaeological assemblages, but emphasize the equally important role played by these other factors: “There are other major variables besides activities that enter into the ‘making’
of an assemblage, and these lead to a more complex view of how 'function' can be expressed in the composition of an assemblage.” They then construct a formal model in which the type and relative frequency of activities are held constant while tool discard rates and mapping relations are allowed to vary. This produces hypothetical assemblages of varying character, which illustrate the independent effects of these factors (Ammerman and Feldman 1974:614–16).

Ammerman and Feldman’s model can be adapted for use in this study. For these purposes, the most important organizational factor to consider is tool-to-task mapping relations. This is not at all to deny the importance of tool discard rates, but separate treatment of that factor is warranted. Since mapping relations have an impact on the character of archaeological assemblages, it is worth considering what determines the set of relations which obtain in specific cases. In effect, what is the relationship between tool classes and particular activities? Furthermore, why are tool classes applied to one or a few tasks in some instances and to many tasks in others?

The general form of the Ammerman and Feldman model is illustrated in Table 1, which is adapted from their table 1 (1974:611). There, task applications 1–n are denoted by their relative frequencies a1–an. Tool classes T1–Tn are listed by row and are followed by their characteristic discard rates, d1–dn. The latter will remain constant in the following discussion. Mapping relations between tool classes and tasks are given by the m11–mnn coefficients shown as elements of a matrix defined by tools T1–Tn and tasks a1–an. The resulting abundance of each tool class Tn in archaeological assemblages is denoted as μn and is given by the sum across all tasks of the mapping relations of the class with the tasks, as in the following equation (Ammerman and Feldman 1974:611):

\[ \mu_n = d_n (m_{n1}a_1 + m_{n2}a_2 + \ldots + m_{nn}a_n) \]

**TABLE 1**

A Model of Technological Organization

<table>
<thead>
<tr>
<th>Tool Class</th>
<th>Discard Rate</th>
<th>Activities</th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
<th>...</th>
<th>an</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>d1</td>
<td>m_{11}</td>
<td>m_{12}</td>
<td>m_{13}</td>
<td>...</td>
<td>m_{1n}</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>d2</td>
<td>m_{21}</td>
<td>m_{22}</td>
<td>m_{23}</td>
<td>...</td>
<td>m_{2n}</td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>d3</td>
<td>m_{31}</td>
<td>m_{32}</td>
<td>m_{33}</td>
<td>...</td>
<td>m_{3n}</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Tn</td>
<td>dn</td>
<td>m_{n1}</td>
<td>m_{n2}</td>
<td>m_{n3}</td>
<td>...</td>
<td>m_{nn}</td>
<td></td>
</tr>
</tbody>
</table>
The relative frequency of tool class $T_n$ is denoted by $\tau$ and is expressed as the ratio of $\mu_n$ to the sum of the $\mu_1 \ldots \mu_n$.

By this set of relationships, the relative frequencies, $\tau$, of tool classes are expressed as a function not only of tasks, but also of mapping relations and discard rates (Ammerman and Feldman 1974:610). Even with the same set of tasks and tool types, two different cultural systems can produce different archaeological assemblages with different sets of mapping relations and discard rates. These, therefore, can be viewed as organizational factors which intervene between tools and what generally is the ultimate goal of archaeological inference, the tasks to which the tools were applied.

Based on the model formulated by Ammerman and Feldman (1974), the following variables can be employed to characterize forager technologies:

1. Diversity. This denotes the number of distinct tool types or classes, $T$, in the technology.
2. Versatility. This quantity indicates the number of tasks to which tool classes can be applied. It may vary across tool classes, and values can be calculated by class or in the aggregate for complete technological inventories. Versatility corresponds to the mapping relations, $m$, of Table 1.
3. Flexibility. Flexibility increases as the number of task applications, $a$, increases. It differs from versatility in denoting the range of those applications. For instance, a tool class may be designed for use in three distinct task applications. It is therefore more versatile than a tool class designed for a single application. However, its range may be confined to those three applications, all involved in tool manufacture, for instance. A second class may be employed in three applications as well, but these may vary across a wider range of applications, for instance, both tool manufacture and hunting. The second class therefore is characterized by greater flexibility than the first.

With this foundation, the relationship between technology and settlement mobility in forager societies can be assessed.

**MOBILITY AND TECHNOLOGY**

Torrence (1983:13) has noted the effect of settlement mobility on the technology of forager groups: "Due to the relatively high mobility of most hunter-gatherer groups, the gross number of artifacts which can be carried between residences is ultimately limited. Given this constraint, the degree to which specialization of tools can take place is restricted." Following Torrence's suggestion, mobility should place constraints upon technology by imposing carrying costs. The size of a technology cannot increase indefinitely in order to meet the functional demands or requirements of a cultural system unless the ability to carry tools increases at the same time. Clearly, this ability must be limited, although the limits may vary depending on other components of technology such as the availability of transport devices.
The response to constraints imposed by settlement mobility should involve a limit on the size of the tool inventory or even a reduction in its size if increasing mobility reduces the overall transport capacity of the group. Tools may also become smaller and lighter (Ebert 1979; Keeley 1982) and assume a greater range of uses; that is, tools should become less specialized and more multifunctional in character. In addition, tools should be designed to enhance their portability.

There exists a strong ethnographic warrant for these predictions. In an explicit statement on the technological impact of mobility, Lee (1979:119) notes of the !Kung San of southern Africa: “The central features of the economy—sharing, self-sufficiency, and mobility—impose certain design criteria on the tools themselves. !Kung tools are few in number, lightweight . . . and multipurpose.” Of another Kalahari group Steyn (1971:320) observes: “Because of their nomadism, the quantity of possessions has to be limited as people must carry the things they own. Instead of accumulation, therefore, they try to put the essential items of equipment to the widest possible range of uses.”


Since mobility may be such an important constraint on the design of tools and the size of technological inventories, greater understanding of its role in the organization of technology is required. This understanding will have the added virtue of making the study of prehistoric mobility strategies possible from archaeological remains. Since mobility has been identified as one of the principal aspects of forager adaptations in a wide variety of habitats (Binford 1980; R. Kelly 1980, 1983), its study should be one of the most important areas of future research on forager societies. Until we can specify the conditions under which mobility acts as a constraint on technology and can document the way in which this constraint is expressed, an important aspect of the organization of technology will remain poorly understood, and our ability to infer the character of settlement mobility on the basis of archaeological remains will be impaired:

If we are to study mobility strategies for settlement pattern data, then we need to assess the role that mobility strategies play in site formation. That is, what relationships between human behavior and material remains are most responsive to, and hence capable of monitoring, changes in the components of a mobility strategy? . . . In order to answer questions such as these we need to understand the relationship between mobility strategies and the organization of technology, since we must use, for the most part, lithic assemblages from which to make inferences. (R. Kelly 1980:94)
### TABLE 2
Environmental, Technology, and Mobility Data for Ethnographic Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>ET</th>
<th>NPP</th>
<th>Diversity</th>
<th>Complexity</th>
<th>Frequency</th>
<th>Magnitude</th>
<th>Mean Distance</th>
<th>Area</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mbuti</td>
<td>23.8</td>
<td>2209.4</td>
<td>3</td>
<td>3.0</td>
<td>17</td>
<td>73.9</td>
<td>4.3</td>
<td>200.0</td>
<td>Hart 1978, Tanno 1980</td>
</tr>
<tr>
<td>Andaman</td>
<td>21.9</td>
<td>1589.8</td>
<td>8</td>
<td>4.9</td>
<td>8</td>
<td>19.2</td>
<td>2.4</td>
<td>41.0</td>
<td></td>
</tr>
<tr>
<td>Chenu</td>
<td>20.8</td>
<td>1316.8</td>
<td>14</td>
<td>2.8</td>
<td>3.5</td>
<td>39.5</td>
<td>11.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guayaki</td>
<td>20.7</td>
<td></td>
<td>2</td>
<td>3.5</td>
<td>50</td>
<td>295.0</td>
<td>5.9</td>
<td>780.0</td>
<td>Clastres 1972</td>
</tr>
<tr>
<td>Siriono</td>
<td>20.6</td>
<td>2115.5</td>
<td>6</td>
<td>3.5</td>
<td>16</td>
<td>230.0</td>
<td>14.4</td>
<td>780.0</td>
<td>Rydén 1941</td>
</tr>
<tr>
<td>Guayki</td>
<td>20.7</td>
<td></td>
<td>2</td>
<td>3.5</td>
<td>11</td>
<td>275.0</td>
<td>25.0</td>
<td>782.0</td>
<td>Silberbauer 1981</td>
</tr>
<tr>
<td>Guayki</td>
<td>20.7</td>
<td></td>
<td>2</td>
<td>3.5</td>
<td>17</td>
<td>262.5</td>
<td>15.4</td>
<td>260.0</td>
<td>Lee 1979</td>
</tr>
<tr>
<td>!Kung</td>
<td>16.2</td>
<td>666.1</td>
<td>4</td>
<td>4.0</td>
<td>31</td>
<td>248.0</td>
<td>8.0</td>
<td>260.0</td>
<td>Woodburn 1970, 1972</td>
</tr>
<tr>
<td>Aranda</td>
<td>15.9</td>
<td>153.1</td>
<td>8</td>
<td>2.6</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>I. Kelly 1932</td>
</tr>
<tr>
<td>Paiute</td>
<td>12.7</td>
<td>229.4</td>
<td>4</td>
<td>3.0</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Klamath</td>
<td>12.2</td>
<td>134.3</td>
<td>16</td>
<td>3.5</td>
<td>11</td>
<td>84.0</td>
<td>7.5</td>
<td>1058.0</td>
<td></td>
</tr>
<tr>
<td>Twana</td>
<td>12.3</td>
<td>346.6</td>
<td>16</td>
<td>4.9</td>
<td>3.5</td>
<td></td>
<td></td>
<td>211.0</td>
<td></td>
</tr>
<tr>
<td>Montagnais</td>
<td>11.6</td>
<td>378.3</td>
<td>3</td>
<td>3.1</td>
<td>50</td>
<td>2700.0</td>
<td>64.0</td>
<td></td>
<td>VanStone 1982</td>
</tr>
<tr>
<td>Ona</td>
<td>9.0</td>
<td>10.8</td>
<td>3</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>Lothrop 1928</td>
</tr>
</tbody>
</table>

**Note:** ET and NPP values are from R. Kelly (1983, table 4) and unpublished data compiled by Binford. Mobility and technology data are chiefly from R. Kelly (1983) and Oswalt (1976), respectively. Other sources are listed in right-hand column. Hadza values are taken from Woodburn (1970, 1972), who provides several different figures for mobility frequency. A value somewhat between 27-36 per year is indicated (Woodburn 1970:11, 1972:201), and the value of 31, also used by Binford (1980) and R. Kelly (1980), is employed here. The Hadza total distance variable is obtained by multiplying this quantity by the mean distance per move, 8.0 as reported in Woodburn (1972:201). !Kung values are taken from Yellen (1977:60–63). He records 17 residential moves (excluding way stations occupied for 1–2 days in transit between camps) in a roughly six-month period, but indicates that few, if any, additional moves occur during the remainder of the year (Yellen 1977:59). Total distance figures were calculated from data listed in Yellen’s table 3 and maps 5 and 6. It should be noted that the Hadza and !Kung mobility data employed here differ from those used by R. Kelly (1983).

**ET** = effective temperature  
**NPP** = net primary productivity  
**Frequency** = number of residential moves/year  
**Magnitude** = total distance traveled in residential moves/year in km  
**Mean Distance** = average length of each residential move in km  
**Area** = total area occupied in km²
and time. Ideally, these data could be used directly in an assessment of the relationship between mobility and technology by comparing them with Oswalt's (1976) data on the technology of foraging groups. Unfortunately, however, the two groups of data coincide in only some cases, and the most complete data are available for low-latitude groups. Analysis, therefore, will necessarily focus on those groups. Nevertheless, some of the predictions previously set forth concerning the relationship between mobility and technological structure may be evaluated.

**ETHNOGRAPHIC ANALYSIS**

Oswalt (1976) identified two important components of aboriginal technologies: the number of distinct tool types included in the technological inventory (i.e., diversity) and the complexity of the tools. Complexity indicates the number of distinct components, or technounits in Oswalt's (1976) parlance, that comprise a tool (e.g., a spear with a point, foreshaft, and shaft has three technounits). Oswalt's concept of diversity is equivalent to the technology variable diversity which was defined previously. Unfortunately, his complexity variable is not comparable to either versatility or flexibility. However, its use as a proxy measure for versatility will be assessed later in this analysis.

To evaluate the relationships between mobility parameters and components of technology, Pearson's $r$ correlation coefficients were calculated for all pairs of mobility and technology variables listed in Table 2. Results are shown in Table 3. In the following section these results are considered in some detail.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Diversity</th>
<th>Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF</td>
<td>-.6667</td>
<td>-.1087</td>
</tr>
<tr>
<td>ln(MF)</td>
<td>-.8064</td>
<td>-.1403</td>
</tr>
<tr>
<td>MM</td>
<td>-.3175</td>
<td>-.2030</td>
</tr>
<tr>
<td>ln(MM)</td>
<td>-.5435</td>
<td>-.1844</td>
</tr>
<tr>
<td>Mean distance</td>
<td>-.2422</td>
<td>-.2276</td>
</tr>
<tr>
<td>Territory (area)</td>
<td>.0088</td>
<td>.0526</td>
</tr>
<tr>
<td>ln(territory)</td>
<td>-.0722</td>
<td>-.1188</td>
</tr>
<tr>
<td>Use index</td>
<td>-.3534</td>
<td>-.4337</td>
</tr>
<tr>
<td>WM</td>
<td>.7418</td>
<td>.2517</td>
</tr>
<tr>
<td>ET</td>
<td>-.1797</td>
<td>-.0344</td>
</tr>
<tr>
<td>NPP</td>
<td>-.2210</td>
<td>.3671</td>
</tr>
</tbody>
</table>

MF = mobility frequency  
WM = winter mobility (days in main winter camp)  
MM = mobility magnitude  
ET = effective temperature  
NPP = net primary productivity  
Use index is defined in text.
Mobility and Diversity

One of the chief predictions set forth above concerned the relationship between mobility and technological diversity (i.e., the number of tool classes used in the course of daily activities). It was also proposed that mobility may set an upper limit on the number of tools that can be carried. However, this does not necessarily mean that technological diversity decreases, since a reduction in the overall quantity of tools can be accomplished theoretically by a simple across-the-board reduction in the number of items in each tool class. In this situation, there is no reduction in diversity. However, this is not likely to occur. If mobility increases and the constraints associated with it intensify, without a corresponding reduction in the range of task applications, the expected response should be to reorganize the technology by producing a smaller number of more flexible tool classes capable of application to a broader range of tasks. In this fashion, technological diversity would not vary with mobility constraints by the simple addition or deletion of existing tool classes, but by reorganization into a smaller set of classes, each of which would have broader application (i.e., be more flexible).

Mobility frequency may limit the number of tools and, correspondingly, the number of tool classes than can be carried between residences. Clastres (1972:44) observes of the Guayaki of Paraguay, who are characterized by a very high frequency of residential mobility: “The Guayaki Indians are purely nomadic hunters. Consequently, their technology is strictly adapted to a roving existence, in which moving is an almost daily affair. . . . It therefore is immediately apparent that the quantity of goods and instruments the Guayaki can use is limited by what the women can carry.”

We can expect diversity to increase, then, as mobility declines until a threshold is reached. To investigate this proposed relationship, diversity is plotted against two components of mobility, the number of residential moves per year and the total distance traveled in those moves. The two components denote respectively the frequency and magnitude of mobility. Figure 1 shows the relationship between diversity and mobility frequency as measured by the number of residential moves per year. Inspection of the figure shows that the predicted trend clearly is apparent ($r = .67$; attained significance = .0092).

Owing to the apparent strength of this relationship, closer examination of it is warranted. The relationship appears to be geometric in form, and this suggests the operation of threshold effects; just as the size and diversity of a technological inventory will increase only to some maximum value regardless of the magnitude of increase in task applications, so too will it fail to decrease below some minimum value. Some tools, after all, are required in any technological system, since tasks must be performed. These constraints are depicted graphically in Figure 2. The ethnographic data utilized here identify something close to the minimum threshold of diversity, shown as point B in Figure 2. It is unlikely that any forager group can survive with less than two or three subsistence tool classes. The maximum value, however, probably has
not been identified. High-latitude forager groups, renowned for their technological diversity and tool complexity, are largely absent from the data set. Were suitable data available, their inclusion probably would show that considerably greater diversity can be accommodated at low mobility frequency. There is a further implication of this discussion: at low frequency, mobility constraints are greatly weakened, and forager technologies probably are conditioned more strongly by other factors, such as diversity in the subsistence economy (point A in Figure 2).

A natural logarithmic transformation of the variable “number of residential moves per year” (i.e., the mobility frequency variable) may be performed to examine it in greater detail. The result is shown in Figure 3, where an even stronger statistical relationship is found ($r = .81$; attained significance = .0005). A least-squares regression was carried out to define and evaluate the latter relationship, with the following result:

$$D = 19.11 - \ln(MF)4.42$$

where D denotes diversity, MF denotes mobility frequency, and the numerical quantities are constants defined by the analysis. These results are encouraging and strongly suggest that mobility frequency and forager technology are systematically related.
Figure 2. Theoretical Relationship between Mobility and Technology

Figure 3. Diversity and Natural Logarithm of Mobility Frequency
To continue the analysis, attention is given to the relationship between diversity and the second parameter of mobility, magnitude (the total distance covered in residential moves per year). Several investigators have noted the influence of mobility magnitude on forager technologies. For instance, Tanner (1979:45) observes in the case of the Mistassini Cree: "Because they must travel so far between their [winter] territories and the summer settlement, and because they require far larger territories, those who hunt north of the Eastmain River and the Otish Mountains are thought of as more nomadic and have the reputation of having less material goods. . . ." Table 3 shows fairly strong negative correlations between diversity and mobility magnitude, which again tends to confirm theoretical expectations. The relationships are not significant at the .05 level, however. To evaluate the relationship, Figure 4 plots diversity against the natural logarithm of magnitude. Unfortunately, in this case the results cannot be considered definitive, but the postulated trend again is evident ($r = -.54$; attained significance $=.1044$).

To this juncture the analysis has shown that, despite severe limitations in the data, fairly clear relationships exist between two parameters of mobility and the diversity of forager technologies. What is more, the form of the relationships is consistent with theoretically derived expectations. It is clear that, as both of these parameters of mobility become greater, technological diversity tends to decline. Obviously, however, these findings will remain conditional until more cases can be studied.

**Mobility and Versatility**

The previous section presented data which exhibit strong patterning between mobility frequency and technological diversity. This relationship has an implication for the organization of forager technologies: holding constant the number of tasks in which tools are used, a decrease in diversity must be associated

![Figure 4. Diversity and Mobility Magnitude (MM)](image-url)
with a corresponding increase in the number of tasks in which tools are used. Simply put, the fewer the tools, the greater the number of tasks in which each is used. That is, as technological diversity declines, versatility is likely to increase.

This implication is testable, provided satisfactory data exist on the range of activities or functions to which tools are applied. If such data exist, however, they are difficult to find and probably will require a substantial length of time to compile. This is a praiseworthy goal, and one which may be attainable. In the interim, however, proxy measures must suffice. Oswalt (1976) provides one such measure: tool complexity, which has been defined previously. It is plausible to assume that such complexity varies directly with the number of tasks to which a tool is applied (cf. Torrence 1983), although this proposition is not evaluated here. Such evaluation probably will require the inspection of numerous primary sources.

If the model of technological organization presented above is valid, Oswalt’s (1976) complexity measure should exhibit a direct relationship to mobility parameters. To correct for differences in technological diversity among ethno- graphic groups, mean complexity, found by dividing total complexity or number of technounits by diversity or number of tool types, is employed as the proxy measure of tool versatility in this analysis.

In Figures 5 and 6, the relationship between mean portable technological complexity and the two components of mobility is shown. Neither mobility parameter appears to exert a strong influence on technological complexity (for frequency, \( r = -0.11 \); for magnitude, \( r = -0.20 \)). However, Figure 5 shows that three cases—the Twana, Andamanese, and Siriono—form outliers to the relationship. Removing these cases produces an \( r \) value of 0.5229 (significance = 0.0989) for the relationship between complexity and mobility frequency, a substantial increase in the strength of the relationship. No similar improvement is apparent in the case of mobility magnitude (\( r = -0.0661 \)). Therefore, results in this instance are suggestive but not definitive.  

**Logistic Mobility**

Up to this point, mobility and technological organization have been examined chiefly for groups which rely primarily on residential mobility. These generally are foragers in Binford’s (1980) terms, characterized by regular residential moves and the exploitation of areas immediately surrounding residential locations. In contrast, other groups, notably those occupying high-latitude habitats, are collectors and employ mobility strategies that involve frequent and long-distance logistic forays mounted from residential locations (Binford 1980:10).

Logistic forays differ in important respects from residential moves. The latter normally are moves conducted by an entire group, which vacates one area for another. But the same or similar activities, food-getting and otherwise, tend to be carried out at successive residential locations; that is, the group is doing the same things in different places. In contrast, logistic forays are specialized moves executed by comparatively specialized task groups. Honigmann (1954:46)
Figure 5. Complexity and Mobility Frequency

Figure 6. Complexity and Mobility Magnitude
nicely captures the distinction between residential and logistic mobility in his account of the Athabascan Kaska:

Foodgetting among the Indians of the taiga depended thoroughly upon mobility. Although a little travel occurred for other purposes, two main patterns of mobility may be distinguished. First, groups of people moved with their belongings to various parts of the tribal territory in search of new food resources to exploit. Such travel took place, for example, in the fall when the population moved to the mountains and again in early winter when they journeyed down to fish lakes. Second, there took place a great deal of "short term" travel, required of men pursuing game or of women visiting fish nets and berry patches.

As Binford (1980:10) summarizes it:

Specially constituted labor units—task groups—therefore leave a residential location, generally moving some distance away to specifically selected locations . . . in the procurement of specific resources . . . They are not groups out "searching" for any resources encountered; they are task groups seeking to procure specific resources in specific contexts. Thus we may identify specific procurement goals for most logistically organized groups. (original emphasis)

Since different logistic moves are likely to have different purposes, more functionally specific tools may be produced for use in the forays. A comparatively low frequency of residential mobility—not to be confused with logistic mobility—also characterizes logistic systems, and this too would act to reduce carrying costs, even if the total distance involved in residential moves is great. In combination, these factors would have the effect of increasing technological diversity. As previous discussion showed, diversity appears to respond to mobility frequency more than to mobility magnitude.

The practice of logistic mobility among certain groups, therefore, presents an opportunity to further isolate the potentially separate effects of mobility frequency and magnitude on technological organization. Unfortunately, logistic mobility data are sparse for most groups in this sample; of the three logistic mobility variables defined by R. Kelly (1983), only one, winter mobility (WM), has sufficient data to be used in the analysis. Winter mobility denotes the length of occupation (in days) of the principal winter or wet-season camp. As that quantity increases, obviously, fewer residential moves are executed. All else being equal, therefore, WM should vary inversely with overall mobility frequency. Since technological diversity also is related inversely to mobility frequency, diversity and WM should exhibit a positive correlation.

Data on winter mobility are compiled in Table 4; the relationship between diversity and this quantity is shown in Figure 7. Inspection of the data shows
### TABLE 4
Logistic Mobility Variables

<table>
<thead>
<tr>
<th>Group</th>
<th>WM</th>
<th>Use Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mbuti</td>
<td>.37</td>
<td></td>
</tr>
<tr>
<td>Andaman</td>
<td>120</td>
<td>.47</td>
</tr>
<tr>
<td>Chenchu</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>Guayaki</td>
<td></td>
<td>.38</td>
</tr>
<tr>
<td>Siriono</td>
<td>150</td>
<td>.29</td>
</tr>
<tr>
<td>G/wi</td>
<td>30</td>
<td>.35</td>
</tr>
<tr>
<td>!Kung</td>
<td>60</td>
<td>1.00</td>
</tr>
<tr>
<td>Paiute</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Klamath</td>
<td>195</td>
<td>.08</td>
</tr>
<tr>
<td>Montagnais</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Ona</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

WM = winter mobility (days in main winter or wet-season camp)
Use index is defined in text.
Data are from R. Kelly (1983).

![Figure 7. Diversity and Winter Mobility (WM)](image-url)
that diversity is strongly correlated with winter mobility ($r = .7418$; significance = .0221) (see Table 3). Least-squares regression yields the following result for this relationship:

$$D = 2.50 + .05(WM)$$

where $D$ is technological diversity and $WM$ denotes winter mobility. Clearly, then, technological diversity is related to this measure of logistic mobility.

The relationship between winter mobility and mean technological complexity also can be evaluated. In this instance, however, the relationship is not strong ($r = .2517$; significance = .5136) (see Table 3). It is apparent, then, that winter mobility is a poor predictor of technological complexity.

To continue the analysis, diversity may also be compared to a rough index of residential mobility obtained by dividing total distance covered per year in residential moves (magnitude) by total area occupied (see Tables 2 and 4) (R. Kelly 1980:75–76). This index measures, in rough fashion, the intensity of land use characterizing groups, with more intensive use corresponding to high residential mobility. Accordingly, higher values of this index indicate high residential mobility, and, conversely, lower values indicate low residential mobility and greater use of logistic mobility. However, Table 3 and Figure 8 show that no strong trend characterizes the relationship between diversity and this index. A similar lack of correlation is apparent between complexity and the index.

Comparison of the Twana and Tlingit of the North American Northwest Coast also is instructive in the evaluation of technological organization in logistically mobile systems. Schalk (1981) argues that Northwest Coast groups are characterized by increasing mobility, especially logistic mobility, from south to north. He records a group range size for the Twana of approximately 210 km², while the similar Tlingit figure is 2,500 km² (Schalk 1981:60). Other
mobility data are lacking, but these figures and Schalk's general conclusion indicate that the more southerly Twana are less mobile than the Tlingit. Twana portable technological diversity is 16, compared to a value of 12 for the Tlingit (Oswalt 1976). More importantly, Twana overall diversity, which includes non-portable facilities such as traps and snares, is nearly twice the comparable Tlingit figure. This observation lends support to Hitchcock's (1982b:380) assertion that one major consequence of reduced mobility is the expansion of the nonportable technological inventory.

In summary, technological diversity exhibits a strong correlation with one measure of logistic mobility—winter mobility—but not with the other measure. Again, technological complexity displays a considerably weaker relationship to mobility parameters.

Technology in High-Latitude Habitats

Data were insufficient to examine the relationship between residential mobility and diversity for groups in temperate to arctic latitudes, and suitable estimates could not be derived. However, the relationship between the mobility and technological organization of these groups probably is more complex than that observed for low-latitude groups. This is partly because of the necessary increase in diversity as seasonality becomes more pronounced. However, high-latitude groups also utilize draft animals, such as dog teams, and water craft in transport (Murdock and Morrow 1970). These have the effect of increasing the bulk transport capacity of such groups, thus altering the relationship observed for groups among which only human carriers and foot travel are available. In fact, the renowned complexity of arctic technologies may be difficult to sustain in the absence of bulk transport: "Men recognized that the gear varied with the mode of transport. . . . If the sled was being used, there was always a few extra drill bits, preworked wooden and antler pegs, rawhide lashing, extra elements of dog harness, and more 'carving tools' . . . ." (Binford 1979:263). Under these conditions, the role of mobility in technological organization is reduced, and technological diversity probably is strongly correlated with resource diversity or the range of tasks requiring the use of tools. However, until more data are available, these expectations cannot be evaluated.

Mobility, Technology, and Territory

In addition to total distance moved per year, the mobility data also include figures for territory size. For several reasons, the territory size figures were considered somewhat unsatisfactory. In the first place, data were available for only nine of the groups employed in this analysis. Primary sources on a number of other ethnographic groups yielded very rough territory size estimates, and only in a few cases were such figures given in original accounts. Furthermore, some figures listed in original accounts obviously referred to the territory occupied by entities such as language groups rather than local groups. In other cases, it was not clear to which organizational level the figure referred. In the absence of reliable direct data, estimates provide the only alternative. For most
TECHNOLOGICAL ORGANIZATION AND SOCIAL MOBILITY

Archaeologists often equate mobility with territory size, on the assumption that all forager societies utilize their territories in similar fashion. This is a highly questionable assumption (Binford 1983; R. Kelly 1983:296), and previous discussion has shown that the character and complexity of forager mobility strategies are highly variable. Using territory size as even a rough measure of mobility, therefore, is apt to be misleading. It is unlikely under these circumstances that clear patterning will characterize the relationship between forager technology and territory size.

Nevertheless, the relationship may be examined using extant data. Table 3 shows that no statistically significant results were obtained between technology components and territory size, nor between those components and the log-transformed territory variable. This leads to the conclusion that no systematic relationship exists between technology components and the territory size occupied by forager groups.

Technology and Environmental Parameters

As a final step in the analysis, mobility components were compared to the environmental parameters of effective temperature (ET) and net primary productivity (NPP). R. Kelly (1983) has treated the issue in some detail and has shown how these parameters structure forager mobility strategies. Their effects on forager technology, however, are less apparent, as inspection of Table 3 shows. No significant correlation values were obtained. Whatever their merit in explicating mobility strategies, it appears that these environmental parameters are not closely related to technology in forager societies.

Summary

The results presented above show that the two components of forager technologies—diversity and mean complexity—are related to mobility parameters in somewhat different ways. Technological diversity is more closely related to mobility frequency than to mobility magnitude. Conversely, mean complexity exhibits a stronger correlation with mobility magnitude, although the relationship is weaker in this case. These findings suggest that it is inappropriate to employ mobility as an undifferentiated variable in analysis (Binford 1980; Eder 1984); instead, mobility itself is composed of several distinct parameters. Future studies of mobility and technological organization must carefully specify which mobility parameter is being evaluated for its relationship to which component of forager technology, because those mobility parameters may have effects upon technological organization independent of each other.

Although not definitive, sufficient agreement with the expectations generated by a consideration of mobility and technological organization has been found to warrant further investigation. Relationships such as those involving mobility
and technology are likely to be complex and to be complicated by other factors (Hitchcock 1982b:372). Under these circumstances, simple and clear relationships should be the exception rather than the rule. Nevertheless, several clear relationships are apparent, lending support to the general proposition that settlement mobility and technology are related systematically in forager societies.

Traditional archaeological analyses of stone tool assemblages assume that the diversity of functional tool classes in an assemblage accurately reflects the diversity of task applications in which the tools were employed. However, this analysis has shown that other factors, mobility frequency most notably in this instance, may complicate the assumed correspondence. If technological organization is used as a framework for analysis, it is clear that archaeologists cannot assume that simple, direct relationships hold between task applications and tool assemblages (Binford 1977a; Draper 1985).

THE DEVELOPMENT OF MIDDLE RANGE THEORY

Thus far, discussion has concerned ethnographic data and the ethnographically documented technologies employed by various forager societies. The development of archaeological implications of the relationships between settlement mobility and technology will require the construction of an additional set of middle range arguments (Binford 1977b:10) linking the theoretically derived relationships with archaeological remains. For several reasons, this task will not be simple or straightforward. The complexities of technological organization in functioning systems are substantial, but the additional complications introduced in archaeological contexts are more daunting still. Since lithics are virtually the only universal archaeological remains of forager societies, and because of their ubiquity, they must occupy a central role in the effort. But the components of organization identified in functioning technologies—diversity and versatility—cannot be translated directly into meaningful archaeological terms because lithics usually comprise a small portion of a complete technology (Hayden 1977; Oswalt 1976).

Although the development of relevant middle range arguments will be difficult and protracted, a number of propositions can be advanced as a point of departure. Binford (1977a), for instance, has proposed a set of organizational implications for the size and character of debris assemblages that may prove useful. Attention will be confined here, however, to the character of tool assemblages.

Lithic Tools

Diversity is a property of technological assemblages, not of individual tool types. To the extent that morphologically distinct tool classes can be identified in archaeological lithic assemblages and functions imputed to them reliably, the number of such classes can stand as a measure of diversity. However, the definition of these classes usually should be based on attributes of the blank
forms from which tools are produced or on hafting attributes, since no direct relationship between morphology and function characterizes most forager technologies. Furthermore, how reliable this diversity measure will be is unknown, since a substantial degree of cross-cultural variability exists in the use of stone. Lithics ordinarily comprise a very small percentage of forager technologies. This may or may not pose a problem, since viewing lithics as samples of technologies enables archaeologists to evaluate their accuracy in representing diversity. Wide agreement exists that sample size is not necessarily related to sample accuracy, and even small samples may accurately reflect overall diversity (Cochran 1977; Cowgill 1975). With respect to lithics as representative of complete technologies, however, this remains a testable proposition and not an established relationship. It requires the use of ethnographic data to evaluate its validity.

Tool versatility and flexibility must also be clearly distinguished. In archaeological contexts, versatility can be measured by the number of distinct functional attributes or segments on tools, as far as those can be determined. However, this measure is only partly satisfactory and should be considered provisional, since a single functional segment of a tool may be used in more than one application. As mentioned previously, systematic ethnographic data on tool versatility is difficult to acquire, but, once more, further effort may yield useful data. While versatility measures the number of task applications in which a tool is employed, flexibility indicates the range of those task applications. In archaeological contexts, flexibility can be measured by examining the relationship between functional attributes and attributes of tool management or curation, such as hafting (Keeley 1982). In a comparison of different tool classes defined on the basis of hafting criteria, the more versatile class may be the one exhibiting a greater number of discrete functional attributes. Similarly, the more flexible class may be identified as the one displaying a broader range of functional attributes.

Clearly, these proposed measures of technological organization are tentative. They will require a considerable amount of theoretical elaboration and empirical testing before they can be used with confidence. But it is indices such as these, or others which prove more useful, that will allow us to observe and measure changes in forager mobility strategies in the archaeological record.

Moreover, although certain effects of mobility on technology have been identified here, direct archaeological applications of these results will require the development and testing of a further set of proposed relationships linking technological organization to archaeological remains and formation processes. Among the important variables whose roles must be assessed are curation (Binford 1977a) and the brief, expedient use of lithic tools that have not been intentionally modified to assume recognizable tool forms (see, e.g., Gould, Koster, and Sontz 1971). In addition, methods of measuring or estimating tool use-lives must be developed, and the manner in which diversity and versatility in functioning technologies is expressed in only the lithic component of those technologies must be identified. Some research to date (Aldenderfer 1981;
Ammerman and Feldman 1974; Schiffer 1975) has suggested that the relationships of interest are complex and can produce patterns in archaeological assemblages not readily explicable without knowledge of the complexities of technological organization and assemblage formation processes.

Furthermore, the conditions determining the use of stone raw materials and the relative contributions those materials make to complete technological inventories must be specified (Torrence 1983:21). No predictions are offered here, but it is worth noting that stone tools may comprise a surprisingly small percentage of a complete technology. Table 5 shows that the relative percentage of lithics in technology is depressingly low in general for the groups surveyed. The categories of subsistence tools defined by Oswalt (1976) are used to aggregate the data in Table 5. Note especially that the imperishable component of facilities—which include traps, snares, and similar devices—is extremely small, making this class of tools virtually invisible in most archaeological contexts. This point underscores the limitations of the archaeological record for those areas of the world, chiefly temperate to arctic habitats, where facilities are an important component of technological structure (Janes 1983:80).

**AN ARCHAEOLOGICAL EXAMPLE: CODY COMPLEX ANALYSIS**

Several propositions were advanced above concerning the relationship between settlement mobility and aspects of the structure of forager tool assemblages. These aspects include both the attributes of individual tools and tool classes and attributes measurable only at the level of the assemblage (e.g., the relative frequencies of curated and noncurated tools and technological diversity). In this section, some of these propositions can be evaluated against a set of archaeological data.

The example comes from data which Knudson (1973) has compiled on two Cody Complex assemblages from the Great Plains: the Plainview, Texas, site and the MacHaffie site, located in western Montana. Knudson's data (1973, tables D.1 and E.1) include, among other attributes, the length, width, and thickness of tools, tool weight in some instances, and certain haft attributes of bifacial tools. Importantly, they also include the number and kind of employable units (EU), which Knudson (1973:17) defines as "that implement segment or portion (continuous edge or projection) deemed appropriate for

<table>
<thead>
<tr>
<th>Technounits</th>
<th>Instruments</th>
<th>Weapons</th>
<th>Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithic</td>
<td>1.05</td>
<td>2.55</td>
<td>0.65</td>
</tr>
<tr>
<td>Total</td>
<td>9.30</td>
<td>51.25</td>
<td>62.30</td>
</tr>
<tr>
<td>Percent lithic</td>
<td>11</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

Data are from Oswalt (1976).
use in performing a specific task." EU, by this definition, are identified with specific task applications.

Obviously, settlement mobility cannot be directly controlled or measured in an archaeological analysis. That quantity, after all, or its constituent components, is what we seek to infer from relevant attributes of archeological data. However, the distance between the source of the raw material from which tools were fashioned and the location at which they were deposited to enter the archeological record can be used as a measure of mobility. This is necessarily an approximate measure, but one which is consistent with prior archeological usage (Bamforth 1985; Binford 1979; Hester and Grady 1977) and which possesses a great deal of intuitive merit. In all probability, the farther that tools are deposited from their source, the more they have been moved during the period of their use. This is not necessarily true in all cases, however. It should be demonstrated by ethnographic study rather than assumed, but for the present its validity is accepted. However, it is another matter to assert that tool mobility can be identified with the settlement mobility of the foragers who used them (Eder 1984:846). Forager settlement practices, as we have seen, can entail a great deal of complexity, and it is likely that the distance which chert tools are carried from their sources is only an imperfect measure of mobility. It is best used with caution as a measure of mobility, and it probably is best suited for use in cases in which substantial distances are involved. Fortunately, Knudson's (1973) data satisfy these requirements.

The Plainview assemblage was produced from chert whose known sources are located at least a hundred miles from the archaeological location (Knudson 1973:23–24). In contrast, the MacHaffie assemblage is composed of specimens made from locally available chert. Knudson (1973:70) notes the existence of "at least five major quarries within a few miles" of the MacHaffie site. She concludes that, with two probable exceptions in an assemblage numbering seventy-two specimens, all tools are made from locally available raw materials (Knudson 1973:72). For the purposes of this analysis the Plainview assemblage may be considered more "mobile" than the MacHaffie assemblage; that is, as a toolkit employed by a more mobile group, or as a curated toolkit or personal gear (Binford 1977a) as opposed to a noncurated or expedient one.

**Unifaces**

Turning first to the unifacial assemblages from the sites, Table 6 shows summary data for a series of attributes. Inspection of the table shows that the assemblages do not differ in mean length of tools (t = .28, df = 24, p = .78) but are characterized by fairly strong differences in tool width (t = 1.27, df = 24, p = .21) and tool thickness (t = -1.4346, df = 28, p = .16). The curated Plainview assemblage, therefore, consists of thinner and narrower tools than does the MacHaffie assemblage. This is consistent with the expectation that the size of curated tools should be minimized to reduce carrying costs. Unfortunately, this expectation could not be further evaluated by comparing values of mean weight between the assemblages, since that attribute is reported for only a few specimens in the Plainview assemblage (Knudson 1973, table D.1).
Versatility, according to arguments advanced above, also should vary systematically with mobility. Versatility can be operationalized in these assemblages by using the number of EU per tool. Table 6 shows that the assemblages exhibit a strong difference in this respect ($t = 1.89$, $df = 28$, $p = .07$), with the mean value for the Plainview assemblage being 3.6 EU per tool, exceeding the 2.5 MacHaffie figure by a considerable margin. At least in the comparison of these assemblages, mobility and versatility are strongly related.

Flexibility has been distinguished from versatility above. While the latter refers to the number of task applications per tool, the former concerns the range of those applications. That is, more flexible tool classes can be applied to a broader range of tasks given constant versatility. For the assemblages under analysis here, the range of EU and the evenness of the distribution of tools across EU categories are the relevant variables for comparing their flexibility.

Since Knudson's (1973) data have been aggregated to some extent, the assemblages (Table 7) exhibit virtually the same range of task applications (i.e., the same EU). (Note, however, that EU 7 is not represented in the MacHaffie assemblage, despite its larger sample size.) Nevertheless, Table 7 shows that EU in the Plainview assemblage are more equitably distributed across the categories than in the MacHaffie assemblage. In the latter, categories 1, 3, and 5 account for 66 percent of all EU. The Plainview assemblage, in contrast, does not exhibit a comparable degree of clustering in EU categories. A maximum likelihood test of the independence of the observed frequency distributions yields significant results ($L = 12.58$, $df = 7$, $p = .08$). These observations lead to the conclusion that flexibility is greater in the Plainview assemblage.
than in the MacHaffie assemblage, a finding also consistent with theoretical expectations.

To continue the analysis, attention now is turned to the degree of standardization exhibited by metric attributes of the tools. The more mobile Plainview assemblage should exhibit greater standardization than the MacHaffie assemblage in those attributes related to hafting, since mobile, curated tools are likelier to be hafted than expedient tools (Ebert 1979; Keeley 1982). Hafting, in turn, should impose constraints on metric attributes by requiring a relatively narrow range of acceptable values in order to facilitate the hafting itself (Keeley 1982:801). Among the attributes compiled for this data set, tool width and thickness should be related to hafting more strongly than tool length. The latter should be more a function of the extent of use and consequent resharpening a tool receives (Dibble 1984, 1985; Keeley 1982:801). Following this logic, the Plainview tools should exhibit greater variability in length than in width and thickness and should show less variability in these latter two attributes than the MacHaffie assemblage. Such variability can be expressed by the coefficient of variation (CV) (Simpson, Roe, and Lewontin 1960:90) which is calculated as the ratio of standard deviation to mean, multiplied by 100. Table 8 shows the relevant values for the two assemblages. For length, the Plainview CV actually exceeds the MacHaffie value, although the difference between them is negligible. In contrast, Plainview width and thickness values are considerably less than those characterizing the MacHaffie assemblage. This supports the expectations outlined above and suggests that curated tool form is conditioned to some extent by haft requirements. In summary, Plainview unifacial tools are more standardized in width and thickness than in length and are more standardized for those variables than the MacHaffie assemblage. The low variability in tool width and thickness observed in the Plainview assemblage may reflect the hafting requirements of tools and lends further support to the arguments presented here.

Reduction Sequence

To this juncture, analysis has shown that mobility carries implications for the design and use of stone tools. Specifically, tool versatility and flexibility have been seen to vary with the apparent mobility of stone tools in the Plainview and MacHaffie assemblages. This suggests that the more mobile Plainview

TABLE 8
Standardization of Cody Complex Unifaces

<table>
<thead>
<tr>
<th>Site</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length</td>
</tr>
<tr>
<td>Plainview</td>
<td>37.5</td>
</tr>
<tr>
<td>MacHaffie</td>
<td>29.3</td>
</tr>
</tbody>
</table>

EU = employable units
assemblage is comprised of curated tools (Binford 1977a), or at least more extensively curated tools, than the MacHaffie assemblage. Dibble (1984, 1985) has formulated a reduction model to account for transformations in the form of such tools as they proceed through a reduction process. He has argued convincingly that morphological distinctions between specimens correspond to stages in the reduction process, rather than to functional differences between discrete types (cf. Bordes 1961). Dibble’s success in accounting for differences in tool form suggests that his model possesses considerable merit. Accordingly, it can be evaluated further using data from the assemblages under study here.

Knudson (1973, table D.2) has presented data on the platform attributes of the Plainview assemblage tools which include platform thickness and width. Following Dibble (1985), the size of tools can be approximated as the product of their length and width. Original size of the flake blank in turn can be estimated as the product of platform thickness and width (Dibble 1985:12). The ratio of these two quantities can be interpreted as a measure of the difference between original size and final size, and size reduction can be equated with the degree of resharpening undergone by a tool (Dibble 1985:12). Finally, the extent of reduction can be interpreted as a measure of the degree of utilization, and consequently of curation, of the tool.

According to this argument, more heavily resharpened tools are more heavily curated tools. More heavily curated tools, in turn, should exhibit greater versatility than other tools. Employing the number of EU as a measure of versatility, as above, Table 9 shows that the data from the Plainview assemblage platform flakes are consistent with this interpretation. The ratio exhibits a strong negative correlation with the number of EU; that is, as resharpening increases, probably as a result of curation, the ratio decreases and the number of EU also increases. However, low sample size renders the result statistically insignificant. Spearman’s rho statistic, a suitable alternative to parametric statistics such as Pearson’s $r$ correlation coefficient (Siegel 1956:202–13) computed for these variables yields a similarly high value of $-0.72$. Unfortunately, no comparable data on the MacHaffie assemblage are provided by Knudson (1973), so examination of these relationships cannot be extended.

**Bifaces**

In the ethnographic cases, technological diversity was found to vary inversely with at least one major component of mobility, frequency. Although Knudson

<table>
<thead>
<tr>
<th></th>
<th>Flare Size</th>
<th>Platform Size</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>.10</td>
<td>.48</td>
<td>$-.80$</td>
</tr>
</tbody>
</table>

EU = employable units

---

TABLE 9
Correlation of EU with Uniface Metric Attributes
(1973) does not define types rigorously nor tabulate her results in this respect, it is clear that a greater diversity of tool types characterizes the less mobile MacHaffie assemblage. While the Plainview biface assemblage is confined to three types (Knudson 1973, figs. D.4–D.8), termed Varieties I–III by Knudson, the MacHaffie assemblage includes all those types as well as a series of "irregular" bifaces (fig. E.19a–g), "specialized" bifaces (fig. E.20a, d), large bifaces (fig. E.15), bifacially retouched flakes (fig. E.7), "para-Levallois" flakes (fig E.11), cores (fig. E.14), and core fragments (fig. E.2, fig. E.22). Clearly, technological diversity is greater in the MacHaffie assemblage, a finding consistent with theoretical expectations.

It is plausible that part of the difference in diversity between the assemblages is attributable to sample size (Kintigh 1984), which is thirty-three and seventy-two, respectively, for Plainview and MacHaffie (Knudson 1973:23, 70). It is unlikely, however, that this factor entirely accounts for the difference, which is considerable. At any rate, this proposition will remain untested until the relationship between technological diversity and sample size can be evaluated for a large number of archaeological lithic assemblages.

Summary statistics for the metric attributes of the Plainview and MacHaffie assemblage specimens are listed in Table 10, which is compiled from Knudson's (1973) tables D.1, D.3–D.6, E.1, and E.15–E.17. For purposes of analysis, the MacHaffie assemblage can be divided into two groups, one consisting of all specimens and the other of Variety I–III bifaces. The latter group is comparable to the Plainview assemblage in tool morphology and probable production sequence. Therefore, the Plainview assemblage can be compared first to the total MacHaffie assemblage and then to the subdivision of the latter. In this manner, it may be possible to detect differences within as well as between assemblages in the variables of interest. Several predictions set forth previously can be evaluated using these data.

For instance, it was postulated that mobility should promote the use of smaller and lighter tools. Although data on tool weight are lacking for the Plainview assemblage, Table 10 shows that the chief dimensions of tools—length, width, and thickness—all are smaller for the Plainview assemblage than for the total MacHaffie assemblage. Student's t-tests calculated for differences between assemblage mean values yield significant results in most instances (for length, \( t = -1.44, df = 28, p = .16 \); for width, \( t = -3.18, df = 28, p < .01 \); for thickness, \( t = -2.63, df = 28, p = .01 \)). Similarly, using the number of EU per tool as a measure of tool versatility, the Plainview value exceeds that for the total MacHaffie assemblage (Table 10). Interestingly, the difference is relatively small and is not statistically significant (\( t = .12, df = 27, p > .90 \)). Therefore, although versatility appears to vary directly with mobility, the relationship is weak.

When comparison is confined to the members of the MacHaffie assemblage which are similar typologically to the Plainview assemblage specimens, a somewhat different pattern emerges. This is not surprising in view of the fact that this segment of the MacHaffie assemblage probably represents the curated
### TABLE 10
Metric Attributes of Cody Complex Bifaces

<table>
<thead>
<tr>
<th>Site</th>
<th>Length</th>
<th>Width</th>
<th>Thickness</th>
<th>EU</th>
<th>Resharpening</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Haft Attributes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Length</td>
</tr>
<tr>
<td>Plainview</td>
<td>61.82</td>
<td>23.49</td>
<td>6.15</td>
<td>2.58</td>
<td>32.01</td>
</tr>
<tr>
<td>MacHaffiea</td>
<td>71.77</td>
<td>26.89</td>
<td>7.84</td>
<td>2.57</td>
<td>18.30</td>
</tr>
<tr>
<td>MacHaffieb</td>
<td>72.91</td>
<td>36.99</td>
<td>13.70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- a. Variety I–III bifaces only
- b. Entire assemblage

EU = employable units

### TABLE 11
Standardization of Cody Complex Bifaces

<table>
<thead>
<tr>
<th>Site</th>
<th>Length</th>
<th>Width</th>
<th>Thickness</th>
<th>EU</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Haft Attributes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Length</td>
</tr>
<tr>
<td>Plainview</td>
<td>18.21</td>
<td>7.94</td>
<td>21.19</td>
<td>19.90</td>
<td>25.50</td>
</tr>
<tr>
<td>MacHaffiea</td>
<td>47.23</td>
<td>31.47</td>
<td>32.76</td>
<td>24.09</td>
<td>24.15</td>
</tr>
<tr>
<td>MacHaffieb</td>
<td>34.80</td>
<td>36.46</td>
<td>62.10</td>
<td>57.83</td>
<td></td>
</tr>
</tbody>
</table>

- a. Variety I–III bifaces only
- b. Entire assemblage

EU = employable units
portion of the assemblage. In this situation, differences between the assem-
blages should be reduced. Returning to Table 10, it is evident that differences
in mean metric attribute values are substantially less in most instances. Note
especially that the MacHaffie values for width, thickness, and number of EU
converge sharply toward the Plainview values. Tool length, in contrast, does
not differ appreciably from the overall MacHaffie value. Evaluation of the dif-
fferences, however, continues to yield statistically significant results (for length,
t = - .95, df = 17, p = .36; for width t = - 1.46, df = 17, p = .16; for thickness,
t = - 2.37, df = 17, p = .03). The result for length attains a lower significance
probably because of the smaller sample size. The margin between Plainview
and MacHaffie values is nearly the same in this instance as when all MacHaffie
specimens are considered. But it is clear that Plainview tools remain smaller
in all respects than their counterparts in the MacHaffie assemblage. Nearly
identical values for the number of EU, however, yield insignificant results
(t = .04, df = 17, p = .95), leading to the conclusion that no difference in tool
versatility characterizes the two assemblages.

Significant differences exist, however, when the degree of tool standardiza-
tion is investigated using the coefficient of variation (CV) as a measure. Table
11 shows that values for the Plainview assemblage are uniformly lower than
MacHaffie values by a considerable margin. Greater standardization is indicated
by lower CV values, and Table 11 thus shows that the Plainview assemblage
is more standardized. With respect to tool width, this probably is a function
of hafting requirements and suggests that assemblages employed in more
mobile contexts are subjected to greater hafting constraints. For length, how-
ever, the difference may reflect the greater degree of resharpening undergone
by the Plainview specimens; that is, as resharpening increases, the range of
variation in the length of completed tools declines. The high value for the
"curated" portion of the MacHaffie assemblage may indicate that the toolkit
was abandoned before most tools were approaching exhaustion. Since many
tools still would be fairly long while others may have been more heavily re-
sharpened, a wide range of variability in length would be the result. For the
number of EU, the low Plainview value is exceeded only narrowly by the value
associated with the curated MacHaffie specimens, but both values are far lower
than the overall MacHaffie figure. This situation suggests that the higher value
for the total MacHaffie assemblage is produced by great differences between
tools in the extent of use and, correspondingly, in the number of EU they
bear. Conversely, mobile, curated technologies, like the Plainview assemblage,
are characterized by more versatile tools, and the degree of standardization
in EU appears to rise as well.

Knudson (1973, tables D. 6 and E. 17) also presents data on the haft attributes
of tools which can be employed in this analysis. Since haft attributes of MacHaffie
assemblage specimens are listed by Knudson only for Variety I–III bifaces,
analysis is confined to a comparison between this curated MacHaffie assemblage
and the Plainview assemblage. Knudson's haft attributes include length of haft
(measured by the length of abraded tool proximal margins) and width and
thickness measured at the distal end of the haft. Table 10 shows that the Plainview assemblage values exceed the comparable MacHaffie values in haft length and width (for haft length, \(t = 3.30, df = 17, p < .01\); for haft width, \(t = 3.26, df = 13, p < .01\)). The Plainview haft thickness value is also greater than the MacHaffie value, but the difference is smaller (\(t = 1.19, df = 17, p = .25\)). No major differences between the two assemblages characterize the CV values for these variables (see Table 11). These findings depart from theoretical expectations. Although the Plainview assemblage, identified with greater mobility, is smaller in the mean values of overall metric attributes, its haft attributes are larger. We would expect haft attributes of the Plainview assemblage to be smaller, but they are not.

By use of another variable, however, it is evident that Plainview assemblage tools exhibit a greater degree of resharpening than do MacHaffie assemblage bifaces. Dividing total length by haft length of all intact specimens gives a measure of the degree of resharpening. This quantity is termed the resharpening ratio in Table 10 and subsequent discussion. In general, the shorter a tool is in relation to the length of its haft, the more it has been resharpened and reduced from its original size. Therefore, as resharpening and reduction increase, the resharpening ratio declines; lower values of the ratio are associated with greater resharpening. This relationship assumes, of course, that a similar ratio of total length to haft length characterized original, unmodified specimens in both assemblages. This measure of resharpening shows agreement with theoretical expectations (see Table 10). The more mobile Plainview assemblage exhibits a lower value, indicating that tools in that assemblage have undergone a greater degree of resharpening than MacHaffie specimens (\(t = -1.46, df = 14, p = .16\)).

Turning from comparison of mean metric values to covariation between variables, Table 12 lists Pearson’s \(r\) correlation coefficients calculated between overall metric attributes and the two measures of tool use, number of EU and the resharpening ratio. (The MacHaffie assemblage has too few intact specimens for the calculation of correlation coefficients between EU and other variables.) Several high values are attained, but only one, the correlation between number of EU and thickness in the Plainview assemblage, is significant.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Length</th>
<th>Width</th>
<th>Thickness</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plainview</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU</td>
<td>.49</td>
<td>.12</td>
<td>.64</td>
<td></td>
</tr>
<tr>
<td>Resharpening ratio</td>
<td>.32</td>
<td>-.46</td>
<td>-.20</td>
<td>-.33</td>
</tr>
<tr>
<td>MacHaffie</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resharpening ratio</td>
<td>.50</td>
<td>.87</td>
<td>.34</td>
<td></td>
</tr>
</tbody>
</table>

EU = employable units
at the .05 level. This probably reflects the heavier utilization of larger tools (as measured by thickness), a pattern also observed by Bamforth (1985:249) in the Paleo-Indian assemblages from the Lubbock Lake site. The high overall values in the MacHaffie assemblage for the resharpening ratio variable probably are due to small sample size. The relationship between certain variables bears closer examination. In particular, the negative correlation between number of EU and the resharpening ratio in the Plainview assemblage is noteworthy. To reiterate, as the ratio declines, degree of resharpening rises. Therefore, a negative relationship between these variables denotes an increasing number of EU on more heavily resharpened tools. This finding is in agreement with the results of the uniface assemblage analysis and indicates that versatility increases with mobility and tool curation.

**Conclusion**

The results of the analyses presented above are encouraging. Predictions based on the theoretical model relating settlement mobility to technological organization have been generated. They have been evaluated against archaeological data, where suitable measures exist for the organizational variable of interest. Strong agreement with theoretical expectations has been observed in most cases. This lends additional credence to the theoretical model, as well as establishing the possibility of testing the theoretical expectations against real archaeological data. These results provide a good starting point for the continued analysis of the relationships between mobility and technology.

**PATTERNING IN ARCHAEOLOGICAL ASSEMBLAGES**

Recent research has emphasized the important role that material culture plays not only in narrowly defined material and energy-processing contexts, but in a much wider variety of social processes as well. The concept of technological organization provides a framework for the recognition and study of this role. It is clear that material culture is conditioned by various communication and boundary maintenance processes (Welch 1981; Wobst 1977), and, as the foregoing analysis has demonstrated, it also can be related to settlement mobility.

An important archaeological implication lies at the heart of these relationships. As settlement mobility declines, material culture inventories tend to increase (Hitchcock 1982a, 1982b). One reason for this is, of course, the removal of a constraint established by mobility and the transport costs connected with it. A second reason, however, is suggested by the demonstrated importance of material culture in social processes and interactions. Material culture can be utilized to transmit a variety of messages concerning social affiliation and status. It is not inconceivable that particular classes of items can be created primarily or exclusively for such purposes, rather than for what archaeologists might consider strictly utilitarian purposes (Wobst 1977, 1983). As constraints imposed by settlement mobility and other organizational factors
are weakened or removed, then material culture inventories should increase, and they should more often be employed in nonutilitarian contexts. Such uses and contexts may be considered task applications with the same logic applied to more objectively utilitarian contexts. For a given set of such task applications, a wider range of material item classes or media become available as the material inventory increases.

Perishable materials frequently are more plastic and widely available than imperishable ones. For these reasons, they probably are more often selected for use in nonutilitarian task applications. This would leave imperishables, notably lithics, with a reduced role in nonutilitarian contexts. To the extent that such contexts are important in imposing structure on material culture like lithics (Wobst 1983), much of the structure and patterning in lithic assemblages can be lost with sedentism.

For instance, Tindale (1965) reports that utilitarian lithics among the Australian Ngadadjara generally consist of unmodified flakes. The only bifacial implement he records, and the only class of lithic tool curated for a period exceeding several weeks, is the circumcision knife (Tindale 1965:154–56). It is probable that the form of this tool is not dictated by functional requirements, but by social ones; Tindale’s account makes it clear that specimens in this class circulate in extensive social and geographic networks. Purely utilitarian implements do not circulate in similar fashion.

To overcome these problems of the loss of structure in lithic assemblages, it is helpful to employ the perspective furnished by technological organization. That perspective can, as this discussion suggests, explain why lithic material culture may lose much of its morphological structure with major social transformations such as sedentism. The determination of what classes of material culture then assume expanded roles in social processes will require the formulation and testing of additional models of behavior.

NOTES

1. It should be noted that values differing from those presented by R. Kelly (1980, 1983) are reported or can be derived in some cases. Obviously, some differences between sources probably reflect interannual variability in mobility parameters, but the magnitude of divergence is sometimes too great to attribute to this source. This is a common problem that archaeologists encounter in the use of ethnographic sources, since relevant data frequently are not recorded accurately or systematically. R. Kelly’s (1983) data are used in Table 1 in most cases, providing a reasonably consistent treatment of the data. However, different values are employed in several places where primary sources provide data considered somewhat more reliable. All area and distance measurements are metric.

2. R. Kelly (1980, 1983) devised certain indirect measures of settlement mobility that could be used to estimate relevant mobility parameters for some other groups. For instance, he identified a positive linear relationship between precipitation runoff and the number of residential moves per year for certain groups (R. Kelly 1983:294). In
TECHNOLOGICAL ORGANIZATION AND SOCIAL MOBILITY

addition, dependence on fauna in the diet was related to territory size for other groups (R. Kelly 1983:297). These relationships could be employed to produce estimates for mobility parameters for those groups for which primary data are lacking. However, because the validity of the relationships has not been rigorously evaluated and because data are somewhat limited, they cannot be used with confidence. Therefore, they were not employed in this analysis.

3. It bears emphasizing here that Oswalt’s (1976) data are not confined to stone tools; in fact, lithics form a relatively small component of most ethnographic technologies considered here. His study also includes data on the relative frequency of both portable and nonportable tools in technologies. However, only portable tools (instruments and weapons in Oswalt’s terms) are considered here, since the effect of mobility on nonportable components of technology may differ from its effect on portable items (Eder 1984; Gould 1969:77). By definition, nonportable tools are not carried from residence to residence. Unlike portable tools, which are used for only relatively brief periods between longer periods of carrying, nonportable tools are infrequently transported and are employed as stationary objects for most of their functioning use-lives. Henceforth, technological data refer only to portable components of technology. In addition, as noted above, Oswalt’s (1976) data are confined to food procurement technology. Obviously, further treatment of the topic should be expanded to include other classes of technology.

4. Although these data are parametric, the use of nonparametric measures of correlation was also considered prudent owing to the small sample size. To this end, Kendall’s tau rank correlation coefficient (Siegel 1956:213–23) was computed for all pairs used in the analysis. The results of this computation are completely consistent with the results found using the Pearson’s r correlation coefficient; in all cases, the two measures yielded similar values, and they agreed on the statistical significance of correlations whose significance attained at least .01. Pearson’s r values are shown and used here because this measure of correlation is more common and familiar. In addition, because it is a parametric measure, Pearson’s r possesses the virtue of yielding different results with the use of log-transformed variables than with original values. Nonparametric measures, like Kendall’s tau, yield the same result in measuring the correlation of variable pairs whether the original or transformed values of one variable are used.

5. Little data on the actual number of tools ordinarily used and transported can be found in ethnographic accounts. In view of this, technological diversity as defined by Oswalt must be employed as an indirect measure of the size or bulk of technological inventories. Accordingly, it is assumed here that technological diversity accurately reflects the size of technological inventories.

6. Binford (1980:7) and R. Kelly (1980:30) report substantially greater values for both mobility parameters in the Siriono case than does R. Kelly (1983:280). The reason for this discrepancy is unclear. Were those values inserted in Table 2, even stronger agreement with theoretical expectations would be found.

7. The use of R. Kelly’s (1983) values for !Kung settlement mobility, rather than those shown in Table 2, probably would strengthen the relationships observed between the two components of mobility and technological complexity. As noted previously however, the latter values are used since they are based on what is considered to be somewhat more reliable data. When more detailed and accurate data become available, it is conceivable that a stronger relationship than obtained here would be found.

8. The Siriono case forms an outlier in Figure 7. Removing it produces an r value of .9700 (significance = .001).
REFERENCES CITED


