



Raw-Material Availability and the Organization of Technology

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## RAW-MATERIAL AVAILABILITY AND THE ORGANIZATION OF TECHNOLOGY

William Andrefsky, Jr.

*Ethnographic examples of stone-tool makers in Australia and archaeological examples from three different areas in the western United States indicate that the availability of lithic raw materials is an important variable conditioning stone-tool production technology. Attributes of availability such as abundance and quality of lithic raw materials condition the production of formal- vs. informal-tool types. Poor-quality raw materials tend to be manufactured into informal-tool designs. High-quality lithic raw materials tend to be manufactured into formal-tool designs when such materials occur in low abundance. When high-quality materials occur in great abundance both formal- and informal-tool designs are manufactured. Other factors, such as residential mobility or sedentism, are found to be less-important determinates of lithic-production technology.*

*Ejemplos etnográficos de los productores de herramientas de piedra en Australia y ejemplos arqueológicos de tres diferentes áreas en el oeste de los Estados Unidos indican que la disponibilidad de materia prima lítica es uno de los condicionantes más importantes en la tecnología de producción de herramientas de piedra. Se ha encontrado que ciertas características, tales como la abundancia y calidad de la materia prima lítica, son factores importantes en la producción de herramientas formales vs. herramientas informales. Materia prima de baja calidad tiende a ser utilizada en diseños de herramientas informales, mientras que materia prima de alta calidad tiende a ser utilizada en diseños de herramientas formales cuando ésta no es abundante. Cuando materiales de alta calidad son muy abundantes, los diseños de herramientas formales e informales tienden a ser producidos. Otros factores, como movilidad residencial y sedentismo, son determinantes menos importantes en la tecnología de producción lítica.*

Recently archaeologists have become interested in the organization of lithic technology and how it relates to aspects of past human behavior. One of the major components in the study of technological organization relates to the amount of effort expended in the manufacture of stone tools. A convincing argument has been made associating prehistoric mobility with effort expended in tool manufacturing. Generally, sedentary prehistoric populations are identified with an expedient- or informal-tool technology and mobile populations with a formalized tool technology.

The relation between stone-tool production effort and prehistoric mobility has been explored, and analyses have been conducted that demonstrate a link between the two (Andrefsky 1983, 1991; Bamforth 1986, 1990; Kelly 1988; Morrow and Jefferies 1989; Parry and Kelly 1987; Shackley 1990; Torrence 1983, 1989). However, there is a second variable associated with technological organization that is as important as settlement configuration, and may well be a primary factor in how a lithic assemblage is ultimately organized with regard to tool form, production effort, and prehistoric time budgeting. This component is the availability of lithic raw-material resources, here defined by both abundance and quality.

This paper explores the effects of lithic raw-material availability on prehistoric tool-production technology within the context of different settlement configurations. This paper takes issue with the premise that stone-tool production technology can be predictably linked to prehistoric settlement configurations without first considering the availability of lithic raw materials. Before demonstrating the effects of lithic raw-material availability on stone-tool assemblages I briefly review some of the archaeological literature on tool-production effort and prehistoric settlement characteristics.

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## PREHISTORIC MOBILITY AND TOOL PRODUCTION

Recent studies (Henry 1989; Parry and Kelly 1987) exploring the organization of technology have effectively associated lithic technology with prehistoric mobility and sedentism through curated artifacts, the functions of bifacially retouched tools, and core technology. Most studies have established a direct relation between the amount of effort expended in tool production and settlement strategies used by the tool makers. A primary and important distinction has been made between tools with little effort expended in their production (informal tools) and tools with more effort expended in their production (formal tools).

The term "formal" is used in this study to encompass a wide variety of tools that have undergone additional effort in production, whether the production occurred over the course of several resharpening or hafting episodes or in one episode of manufacturing from raw material to finished product. Such tools are positioned at the opposite end of a production continuum that is marked by expedient or informal tools with little or no effort expended in their production. Formal tools have been characterized as flexible tools, or tools that are designed to be rejuvenated and have the potential to be redesigned for use in various functions (Goodyear 1979:4). Torrence (1983:11–13) attributes the characteristics of advance preparation, anticipated use, and transportability to these tools. These tools have generally been linked with populations practicing more mobile settlement strategies (and having short-term site occupations). The logic behind this association rests with the relation between raw-material availability and tool needs or uses. Because mobile groups occupy relatively large areas, they may find themselves in regions where lithic raw materials are not suitable for use as tools, and thus must have ready-made tools available for the tasks at hand. In such cases, portable tools, tools that can be redesigned, or tools that have variable functions are best suited for the situation.

Tools that meet these specifications include bifaces, formally prepared cores, and retouched flake tools. Bifaces can be used repeatedly, even after they become dull, by simple resharpening (Andrefsky 1986; Bienenfeld and Andrefsky 1984; Sollberger 1971). They can also be used for many different tasks (Ahler 1971:108; Lewenstein 1987:160). Bifaces have the added benefit of being highly efficient cores (less overall weight to amount of cutting edge) (Goodyear 1979:4–6). Similarly, formal cores also provide a highly efficient source of usable cutting edges (Andrefsky 1987). Clark (1987) suggests that such cores represent the most efficient form of usable cutting-edge storage. Such a characteristic is desirable for a mobile population that must restrict excess weight. Retouched flake tools also represent a type of tool that is practical for mobile groups. Retouched flake tools are known to have been used for a variety of functions (Odell 1981:327; Siegel 1984). The presence of retouch itself on flake tools is, in many cases, an indication of how the tool was adapted for multiple uses or hafts (Keeley 1982).

Informal tools are unstandardized or casual with regard to form. Expediently made tools are included in this category. These tools are believed to have been manufactured, used, and discarded over a relatively short time period. Binford (1979) characterizes such tools as situational gear or gear that is put to use in response to conditions rather than in anticipation of events or situations. This kind of technology is wasteful with regard to lithic raw material, and tends to produce tools that are simpler and have less formal patterning of shape or design.

Informal tools are thought to be associated with more sedentary populations (having longer-term site occupations). Unlike mobile groups, which are believed to have manufactured portable tools, sedentary groups do not have to expend extra effort in the production of formal tools. With increasing sedentism there may come a reduction in the spatial scale of resource availability, because such groups may be tethered to their relatively permanent residential locations and fixed food resources. Weight restrictions for tools are no longer a consideration for more sedentary groups. One advantage possessed by informal tools is the considerably lower amount of work required for their production. Ethnographic accounts and archaeological experiments have shown that tools such as nonretouched flakes and bipolar shatter are quite effective to complete most tasks (Frison 1979:259–268; White 1967:409–411; White and Thomas 1972:278–279).

Several studies of prehistoric technological organization (Andrefsky 1991; Bamforth 1990; Parry

and Kelly 1987) recognize that lithic raw-material availability plays a part in the organization of production but have rarely presented evidence to demonstrate the effects of availability on tool-production effort and prehistoric behavior. I suggest that mobile prehistoric populations would not necessarily produce formal tools if good-quality lithic raw materials were readily accessible at needed locations. Similarly, if sedentary populations did not have access to readily available lithic raw materials, the production of wasteful informal tools would not necessarily be a common practice. Instead, I suggest that the availability of lithic raw materials will influence the kinds of stone tools produced at a site, and that such influences may be only indirectly related to settlement configurations.

### LITHIC RAW-MATERIAL AVAILABILITY

Archaeological evidence suggests that prehistoric populations have discarded formal tools made of high-quality lithic raw materials when fresh raw materials were close at hand. Gramly (1983) reported “dumping” behavior at a small habitation site outside of the Mount Jasper prehistoric quarry in New Hampshire. In this situation it appears that a prehistoric group traveling from a distant location “retooled” at the quarry and moved on. In the process, they discarded formal tools, which may have been transported from as far away as northern Maine and New Brunswick (Gramly 1983:826). It is not known what the circumstances of travel were for the prehistoric population that retooled at Mount Jasper. Gramly (1983:825) notes that no evidence of major habitation—such as post molds, ceramics, or features—was present, and that the visit was probably transitory. The visit to the area appears to have been primarily for the acquisition of lithic raw material from the nearby quarry, although this has not been demonstrated.

The ethnographic record provides examples of treks by individuals whose primary goal was to obtain lithic raw materials. Some aboriginal populations are aware of the value and location of high-quality lithic materials and have made lithic-procurement expeditions, even over relatively great distances (Gould 1978:831–832; Gould and Saggars 1985:121). Such treks, for the primary, but perhaps not sole, purpose of acquiring lithic materials, are an indication of the importance of lithic materials for tool production. When Binford and O’Connell (1984:407) requested Alyawara aborigines to produce some stone knives (Binford 1986), the Alyawara men first set out on a trek to obtain good-quality lithic raw materials. However, as Binford notes, the Alyawara were not in the habit of making and using stone tools when the request for production of stone knives was made, and it was no longer a common part of their “subsistence routine” to procure raw materials for stone-tool manufacturing. It should also be noted that in these ethnographic examples, good-quality lithic raw materials were not readily available in the local vicinity. Regardless of the specific circumstances associated with raw-material procurement tasks, aboriginal groups have been known to travel great distances to acquire tool-quality lithic raw materials.

The availability of lithic raw materials may be the most important factor in the organization of technology. Although studies (Andrefsky 1991; Henry 1989) have shown that amount of effort expended in tool production tends to correlate with type of settlement strategy, the ethnographic record suggests that the availability of lithic raw materials plays a primary role in the amount of effort expended to produce various types of tools. O’Connell’s work with the central Australian aborigines shows that variation in the lithic assemblage is primarily due to the availability of lithic raw materials. O’Connell (1977:280) concluded:

It seems fair to say that where such variation is recognized, it is generally seen either as functional, that is, as resulting from differences in the range of activities carried out at particular sites, or stylistic, reflecting certain traditional standards applied in the manufacture of artifacts. There is no doubt that such interpretations are often quite correct. Nevertheless, the data presented here indicate that a substantial amount of inter-assemblage variation may be the result of differences in access to material used in the manufacture of tools and of the particular characteristics of these materials as they affect the form of implements.

To illustrate this point, O’Connell provided stone-tool production information from five sites on the two most commonly used tool types (adzes and scrapers). The data presented in Table 1 were taken from O’Connell’s (1977:279) research. Three sites are located near chert sources, and two

Table 1. Frequency of Lithic Raw-Material Type for Adzes and Scrapers on Five Alyawara Sites from Central Australia.

	Adzes			Scrapers			Total		
	Quartz-ite	Chert	Total	Quartz-ite	Chert	Total	Quartz-ite	Chert	Total
Sites located near chert									
MD/5	2	32	34	4	30	34	6	62	68
MD/13-14	1	11	12	7	11	18	8	22	30
MD/36	0	11	11	0	7	7	0	18	18
Sites located near quartzite									
MD/4-10	8	4	12	31	3	34	39	7	46
MD/38	7	6	13	4	0	4	11	6	17

*Note:* Data from O'Connell (1977:279).

others are located near quartzite sources. The artifact assemblage from each of the sites is biased toward production of tools with locally available raw materials. It should be noted that adzes and scrapers represent tools that can be rejuvenated, resharpened, and rehafted several times during the use life of the tool and that such tools were not made based on the residential status of the group (mobile or sedentary), but instead on the availability of lithic raw materials. Although O'Connell's data do not compare formal- and informal-tool production, they do show that locally available raw materials are preferred over nonlocal raw materials for formal tools.

Gould (1980) also witnessed the effects of raw-material availability with regard to stone-tool production in the western desert of Australia. In his attempts to develop a "grammar" of lithic technology, Gould develops several rules that relate formalized-tool production and use to habitation camps, and more informal-tool production and use to special-purpose task areas. Along with this association is the added correlation of quarried raw materials being used for formalized tools, and nonlocalized (nonquarried) raw materials being used for informal tools. However, he notes that when lithic raw materials are readily available near the habitation camp, the aborigines tended to use the available materials for production of all types of tools, both formal and informal. This observation prompted Gould (1980:134) to generalize "rule number 6":

Whenever random factors of geography place sources of usable stone, whether in the form of quarries or nonlocalized in nature, at or in close proximity to a water source where a habitation base-camp will occur, ease of procurement will outweigh other factors and unusually high percentages of artifacts of these locally available stones will be made, used, and discarded at such campsites.

These ethnographic and ethnoarchaeological examples indicate that raw-material availability plays a primary role in the organization of technology. The use of categories such as informal and formal tools as a means to identify aspects of prehistoric settlement is apt to be misleading if the availability of lithic raw materials is not considered. In the remainder of this paper I describe some archaeological observations that exemplify the effects of raw-material availability on lithic tool assemblages and compare such effects against prehistoric settlement strategies.

#### ARCHAEOLOGICAL OBSERVATIONS ON RAW-MATERIAL AVAILABILITY

Three archaeological cases from different parts of western North America are examined to explore the relation among availability of lithic raw materials, effort expended in tool production, and prehistoric settlement configuration (Figure 1). The first example is from an area where high-quality lithic raw materials are ubiquitous. In this case, both mobile and sedentary prehistoric groups occupied the area. In the next two cases, I examine data from areas with (1) very-poor-quality, but abundant lithic raw materials, and (2) very little lithic raw materials, all of very poor quality. Both mobile and sedentary prehistoric populations are examined.

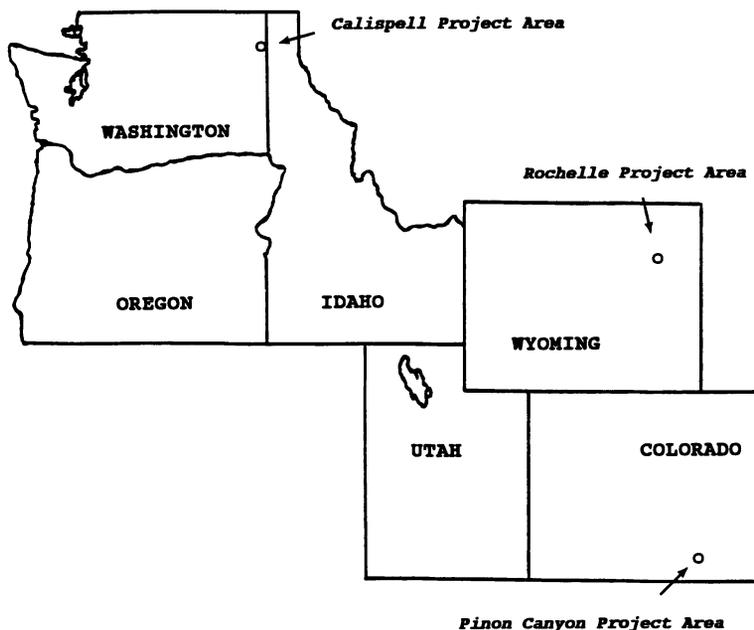


Figure 1. Location of three study areas in the western United States.

#### *Pinon Canyon Archaeological Data*

Data derived from the Pinon Canyon Archaeological Survey are used to evaluate resource availability, effort expended in tool production, and prehistoric settlement. The survey was located in Las Animas County, Colorado, and covered an area of approximately 98,421 ha. Over 2,700 individual prehistoric and historical-period sites were discovered during the course of three field seasons in 1983, 1984, and 1987 (see Andrefsky 1990).

Bedrock in the Pinon Canyon survey area is dominated by Mesozoic transgressive marine sediments (McFaul and Reider 1989). These sediments are locally interrupted by various hills, monoclines, and other smaller flexures. The environment has produced an abundance and variety of lithic raw materials that can be used for tool manufacture. Raw materials occur in nonlocalized settings, such as stream and river deposits, and in localized deposits, such as bedrock outcrops and talus slopes, in all parts of the survey area. Twenty different chipped-stone raw materials were identified in the archaeological record. Locally available raw materials include (1) cherts, (2) quartzites and sandstone, (3) limestone, (4) limestone concretions, (5) argillites, and (6) basalt. Nonlocally available raw materials include obsidian and a form of chert known as Alibates. The obsidian was probably derived from formations in northern New Mexico, and the Alibates chert originated in Texas. Neither occur naturally within the project area. The closest potential source for obsidian is approximately 160 km away in northern New Mexico. Alibates chert occurs naturally over 250 km to the southeast. Additionally, several varieties of lithic raw material were recovered in artifactual form that are from an unknown source location. These raw materials probably originate outside of the survey area but it is not known for sure where, and there is a chance that they occur in nonlocalized settings within the survey area. These include a variety of petrified wood, chalcedony, and a type of chert identified as jasper.

Prehistoric architectural sites within the Pinon Canyon survey area were used as the basis of identification of mobile and sedentary populations. Short-duration occupation sites associated with mobile populations are assumed to be those sites characterized by spaced-stone circles or tipi rings. Sites characterized by aggregations of stone structures are assumed to be the locations of longer-duration occupations. A total of 195 sites contained architecture of some type. Of this number, 86

Table 2. Frequency of Bifacial Cores and Informal Cores by Short- and Long-Term Occupation Sites from Pinon Canyon, Colorado.

Site-Occupation Duration	Core Types		Total
	Bifacial	Informal	
Short term	96 (32.2)	169 (63.8)	265
Long term	31 (34.4)	59 (65.6)	90

*Note:* Numbers in parentheses represent % of artifacts.

sites contained only spaced-stone circles or tipi-ring foundations and were single-component occupations based on the identification of diagnostic ceramics and hafted bifaces. These sites are assumed to represent short-term camp remains of mobile pedestrian or equestrian nomads (Finnigan 1983; Frison 1978:53; Kehoe 1960; Mulloy 1966). The second group of architectural sites, which numbered 14, is thought to represent more longer-term occupations (Andrefsky and Zier 1990; Campbell 1969:336–339). These sites are defined as having stone enclosures or stone-walled features. In most instances these features have multiple rooms and are located in defensible positions along canyon walls and isolated rocky peninsulas (Kalasz 1990). The tool assemblages from both the short-term occupation sites and the longer-term occupation sites were surface collected.

Given the previously cited studies on informal and formal core production, informal cores should be associated with more sedentary sites, and bifacial cores should be associated with more mobile sites. Bifacial cores in this case do not include hafted bifaces (projectile points) or bifacial drills. All other forms of bifaces such as preforms and nondescript bifaces are included in the bifacial core group. Informal cores represent all those lacking a formal shape. Table 2 lists the frequencies and relative frequencies of bifacial and formal cores for short-duration sites occupied by mobile groups and for longer-duration sites occupied by more sedentary groups. It is obvious that there is no significant difference between the two kinds of sites based upon the amount of effort expended in tool production ( $\chi^2 = .092$ ;  $df = 1$ ;  $p < .750$ ). This is unexpected given other studies relating prehistoric mobility and lithic-tool-manufacturing effort. However, given Gould's observations, it would appear that the results obtained from the Pinon Canyon sites can be attributed to a preference for locally available lithic raw materials.

Given the possibility that cores do not accurately depict the level of effort expended in tool production, other classes of tools were examined. Table 3 compares assemblages from short-term and long-term occupation sites by the relative proportion of both formal and informal tools. Formal tools include all bifacial tools as well as various kinds of scrapers, spokeshaves, drills, and retouched flakes. The informal tools represent all nonretouched flake tools and shatter tools. Again, there is no association between tool-production effort and prehistoric mobility. The expected association of informal tools with longer-term site occupation and formal tools with short-term site occupation does not hold. In fact, the relative proportion of bifacial tools is greater (22.2 percent) for sites thought to represent longer-term occupations than for short-duration sites (14.8 percent). Again, this finding may be attributed to the availability of lithic raw materials. The Pinon Canyon survey area contains abundant lithic raw materials in localized and nonlocalized settings. Such a distribution

Table 3. Frequency of Various Tool Types by Short- and Long-Term Occupation Sites from Pinon Canyon, Colorado.

Site-Occupation Duration	Formal Tools	Informal Tools	Total
Short term	524 (52.9)	514 (47.1)	1,038
Long term	130 (53.1)	115 (46.9)	245

*Note:* Numbers in parentheses represent % of artifacts.

Table 4. Frequency of Raw-Material Types for Various Tool Types by Short- and Long-Term Occupation Sites from Pinon Canyon, Colorado.

Site- Occupation Duration	Bifaces			All Formal Tools			Informal Tools		
	Local	Nonlocal	Un- known	Local	Nonlocal	Un- known	Local	Nonlocal	Un- known
Short term	149 (85.2)	13 (7.4)	13 (7.4)	463 (88.3)	24 (4.6)	37 (7.1)	477 (92.8)	22 (4.3)	15 (2.9)
Long term	46 (83.6)	3 (5.5)	6 (10.9)	116 (89.2)	5 (3.9)	9 (6.9)	107 (93.0)	3 (2.6)	5 (4.4)

*Note:* Numbers in parentheses represent % of artifacts.

of raw materials allows mobile populations as well as sedentary populations relatively good access to raw materials for tool manufacturing. As such, the expected association between tool design and mobility does not hold, and this is consistent with the previous analysis of cores.

The ethnographic observations made of central and western Australian aborigines suggest another characteristic of technological organization in situations of readily available high-quality lithic raw materials. In such situations, tools should be manufactured from the local material, and these will be both informal and formal tools. The Pinon Canyon archaeological data listed in Table 4 identify the relative frequencies of local, nonlocal, and unknown provenance lithic raw materials for several categories of tools, and compares these for both short-term and long-term occupation sites. Once again, these data show no difference in raw-material preference between site types. There is also a pattern across all classes of tools for use of locally available lithic raw materials over nonlocal (and unknown) materials. Local lithic raw materials are used to make 90.6 percent of all tools recovered from short-term occupation sites and 91.0 percent of all tools found at long-term occupation sites.

#### *Calispell Valley Archaeological Data*

During the summers of 1985 and 1987 a stratified multicomponent site in the Calispell Valley located in the northeastern corner of Washington state was excavated (Sanders et al. 1991; Thoms and Burtchard, eds. 1986). This site (45PO137) contained a well-preserved record of occupation from approximately 1650 to 950 B.P. (Dohm and Sanders 1991). During this period of time the inhabitants occupied the site on a semipermanent basis for almost the entire yearly cycle. Camas-root procurement was the primary mode of subsistence. Innovations in storage technology and procurement intensification allowed the inhabitants to occupy the site area during times of low resource availability. Evidence of mat lodge structures was also found during excavation (Thoms and Burtchard 1986). Ethnographic data from the area on the Kalispel tribe indicate that mat lodge houses of the kind found during excavation were used during the summer, fall, and winter (Smith 1991).

Inspection of lithic raw-material sources in the region revealed that good-chipping-quality raw materials were not available in or around the project area (Draper 1991; Towner and Draper 1986). There were some poor-quality lithic raw materials in the site area, but these were found in relatively low abundance. Six identifiable lithic raw-material types and one unidentifiable type were recovered in artifact form from excavations. Of the six identifiable types, four originated outside the area. These include cherts, fine-grained mudstones, obsidian, and quartz crystal. The obsidian was traced to a source in eastern Oregon approximately 520 km away, and the cherts, mudstone, and quartz crystal occur on the middle Columbia River approximately 250 km to the southwest. Quartzite and schist, both of poor quality, were found locally and used for the production of some chipped-stone tools (Towner and Draper 1986).

The occupational history at site 45PO137 provides an opportunity to evaluate the effects of scarce low-quality raw-material availability on lithic-assemblage characteristics for a relatively sedentary prehistoric population. Table 5 lists the frequency of tool types against raw-material type. Bifaces include all chipped-stone artifacts that have flakes removed across both opposing faces. This category is composed primarily of projectile points. The category listed as "other formal tools" includes unifaces, such as side and end scrapers, and facially flaked tools such as perforators, graters, and

Table 5. Frequency of Various Tool Types by Lithic Raw-Material Type from Calispell Valley, Washington.

	Informal Tools	Bifaces	Other Formal Tools	Total
Local raw materials	34 (87.2)	2 (5.1)	3 (7.7)	39
Nonlocal raw materials	11 (4.6)	111 (46.3)	118 (49.1)	240
Unknown raw materials	0 (.0)	16 (84.2)	3 (15.8)	19
Total	45	129	124	298

*Note:* Numbers in parentheses represent % of artifacts.

shaped flake tools. The informal-tool category includes unmodified flake tools that may have been used for chopping, scraping, or cutting functions. These are unmodified flakes and spalls that show evidence of use. The most apparent observation based on these data is the extremely low occurrence of tools made from locally available lithic raw materials. Only 39 tools (13 percent) recovered from excavation were made from local materials. The second significant pattern shown in Table 5 is the low occurrence of informal tools. Almost all tools (85 percent) are bifaces or other formal tools. However, there is an association between the type of tools produced and the source of raw materials. Of the 39 artifacts made from locally available lithic raw materials, 34 (87.2 percent) are informal tools. Formal tools constitute 95 percent of items made from nonlocal raw materials. In this case, where high-quality lithic raw materials are not easily accessible and the prehistoric population is relatively sedentary, formal tools dominate the assemblage and tend to be made from nonlocal lithic raw materials. Fewer informal tools are produced, and these are made from local materials.

A third aspect of the analysis of the Calispell data pertains to the quality of raw materials and artifact form. The locally available lithic raw materials are very coarse grained and are difficult to shape. The quality of the local materials stands in sharp contrast to the nonlocal lithic materials, which are very fine grained or cryptocrystalline. The tools that require less skill and craftsmanship for production (informal tools), tend to be made from the poor-quality, coarse-grained raw materials. Bifaces and other formal tools are primarily manufactured from the higher-quality stone.

#### *Rochelle Archaeological Data*

A proposed coal-mining area in Campbell County, Wyoming, was surveyed for archaeological resources in 1981 (Tibesar et al. 1981). A total of 475 archaeological sites and isolated finds was discovered. An area of approximately 2,331 ha was designated as the Rochelle Archaeological District, and in 1984, 17 prehistoric sites spread throughout the district were excavated (Hilman et al. 1986). It was found that the 17 excavated sites represented occupations of mobile hunter-gatherers.

The artifact inventory from the Rochelle Archaeological District includes 15 different types of lithic raw materials. All of these raw materials except one—porcelanite—are derived from outside the district. Porcelanite occurs throughout the archaeological district in nonlocalized form. It is derived from a clay parent material that has been subjected to heat and has hardened into stone. There is a great amount of variation in the porcelanite with regard to hardness and consistency, and although some porcelanite is usable for stone-tool manufacture, a great deal of the raw material is easily crushed and not adequate for chipped-stone-tool manufacturing. Unlike the Calispell Valley case, lithic raw materials are locally available all over the Rochelle district, but are of relatively poor quality. Locally available lithic materials from the Calispell Valley were also of poor quality, but occurred in very low abundance.

The numbers of formal and informal tools made of porcelanite and nonlocal raw materials are listed in Table 6. The formal tools include scrapers and projectile points, and the informal tools include utilized flakes and informal cores. The data show a significant association between type of tool and origin of raw material ( $\chi^2 = 28.82$ ;  $df = 1$ ;  $p < .001$ ). Formal tools tend to be made more

Table 6. Frequency of Expedient and Formal Tools by Lithic Raw-Material Types from Rochelle District, Wyoming.

	Expedient Tools	Formal Tools	Total
Porcelanite	213 (93)	16 (7)	229
Nonlocal	80 (71)	32 (29)	112
Total	293 (86)	48 (14)	341

*Note:* Numbers in parentheses represent % of artifacts.

frequently from nonlocal lithic raw materials, and informal tools tend to be produced from locally available raw materials. This relation is consistent with the Calispell Valley case. However, unlike the Calispell Valley, most of the tools are informal (86 percent). This suggests that when poor-quality lithic raw materials are locally available and in great abundance, they will be used for informal-tool production even by mobile prehistoric groups. Note that when locally available raw materials occur in great abundance and are of high quality, such as was the case in the Pinon Canyon area, there is no preference for production of either formal or informal tools (see Table 3).

#### SUMMARY AND DISCUSSION

Each of the project areas included in this study had differing individual characteristics with regard to raw-material availability (quality and abundance) and the production of formal and informal stone tools. The locally available lithic raw materials from the Rochelle district were ubiquitous, but of poor quality. Most tools were made from this local resource. Almost all artifacts made from local materials were informal. Fewer formal tools were made, and most were manufactured from the nonlocal materials. The Pinon Canyon area also contained locally available lithic raw materials, but unlike the Rochelle example, the Pinon Canyon raw materials were of generally good quality. Consequently, most tools were made from these materials. Formal and informal tools were produced in roughly the same proportion at Pinon Canyon, a much different pattern than at Rochelle. In both cases, however, local materials were used to make the majority of tools, and this pattern conforms to what would be expected given ethnographic observations of local raw-material use when such materials are available.

The Calispell Valley case provided an example of a region with low availability of lithic raw materials. In an area of very low availability of chipping-quality lithic raw materials, inhabitants tend to conserve their tools. The great majority of tools recovered were of the formal variety, and they were predominately made from nonlocal lithic raw materials. Locally occurring lithic raw materials were available in very low frequencies, and the few tools that were manufactured from these materials were mostly informal.

The examples presented above provide some insight into the relationship of raw-material availability as it relates to stone-tool production. The extent to which local lithic raw materials are employed is a function of their abundance. When scarce, nonlocal resources are procured, and are fashioned into formal tools. This relation may be altered in prehistoric systems that have easy access to nonlocal raw materials. In such cases nonlocal raw materials may be as abundant as local raw materials by way of exchange or population movements.

The quality of lithic raw materials also plays a role in structuring tool production. Here, raw-material quality refers to the ease with which the stone can be chipped and controlled in the shaping process. Very-fine-grained homogeneous raw materials tend to be more easily shaped and reduced than coarse-grained and flawed raw materials, and thus represent better-quality stone. Coarse-grained lithic materials are much more difficult to chip and shape in a controlled manner.

Availability of lithic raw materials, particularly with regard to abundance and quality, affects stone-tool production decisions as they relate to formal- and informal-tool designs. When the occurrence of formal and informal tools are considered within the context of these dimensions, a regular pattern emerges. Figure 2 illustrates the relation of raw-material quality against abundance

		<b>LITHIC QUALITY</b>	
		<b>HIGH</b>	<b>LOW</b>
<b>LITHIC ABUNDANCE</b>	<b>HIGH</b>	cell 1  <i>formal- and informal- tool production</i>	cell 2  <i>primarily informal- tool production</i>
	<b>LOW</b>	cell 3  <i>primarily formal- tool production</i>	cell 4  <i>primarily informal- tool production</i>

Figure 2. Contingency table showing the relation between quality and abundance of lithic raw material, and kinds of tools produced. Artifact data from Pinon Canyon fall into Cell 1. Rochelle artifacts fall into Cell 2. Calispell artifact data fall into Cell 4.

for the cases introduced previously. Cell 1 is characterized as having high-quality lithic raw materials in great abundance (Pinon Canyon case). Both formal and informal tools were produced in approximately the same proportions. Cell 2 represents the case where low-quality lithic raw materials occur in great abundance. At Rochelle, informal tools were primarily manufactured; the few formal tools were made from nonlocal sources. Cell 3 represents the instance where mostly high-quality materials occur in low abundance. No example of this occurred in this study, though I would predict a predominance of formal-tool manufacture. Cell 4 represents the co-occurrence of low-quality materials in low abundance. The Calispell case—where informal tools made from local sources predominated—reflects this. In addition, better-quality nonlocal materials were used to fabricate virtually all of the formal tools.

### CONCLUSION

I have argued that an understanding of the organization of technology in relation to issues such as prehistoric sedentism and mobility must consider the availability of lithic raw material to the groups involved with tool production. Ethnographic and archaeological data show the importance of raw-material availability with regard to the production of various tool types, especially as it relates to the production of informal and formal tools. The results presented here suggest that lithic raw-material availability is a significant factor in the organization of lithic technology.

The proposition that lithic-production technology may be directly attributed to the type of settlement configuration was not supported with any of the examples examined here. The analysis of the Calispell Valley data contradicts the notion that sedentary groups will predominately produce

and use informal tools. Formal tools were used by this sedentary group because lithic raw materials were neither abundant locally nor of suitable quality. High-quality nonlocal materials from which formal tools could be fashioned occurred most often. Similarly, the notion that mobile groups should make and use relatively more formal tools than sedentary groups was inconsistent with the Pinon Canyon data. Both mobile and sedentary groups used similar relative frequencies of formal and informal tools. This occurred because lithic raw materials were both locally abundant and of high quality.

If all other variables are held constant, quality and abundance of raw materials may structure stone-tool production in a predictable manner. Low-quality raw materials tend to be manufactured into informal-tool designs. This trend is apparent whether the low-quality raw material are in high or low abundance. High-quality raw materials tend to be manufactured into formal kinds of tools. This is particularly true when the high-quality raw materials occur in low abundance or at some distance. When high-quality raw materials occur in great abundance, as in the Pinon Canyon example, both tool classes are produced in equivalent proportions.

Recently, several papers have attempted explain the variation in lithic-production technology as a multidimensional problem that must account for several potential sources of variation simultaneously (Bamforth 1991; Kuhn 1991; Rolland and Dibble 1990). One implication drawn by these researchers is that in different cases different conditions may combine to shape specific lithic-production technologies. In other words, not only might settlement configuration play a part in the organization of technology, but other factors such as differential transportation of materials, site function, variation in faunal exploitation, and differential attrition rates of various artifact types, may also play a role in the organization of specific technologies. I agree that specific technological variations are best explained in the full context of specific examples, and that every case may have unique conditions that contribute to the final organization of technology. This study represents an attempt to better understand one of the general conditions that contributes to the organization of technology—lithic raw-material availability. The quality and abundance of lithic raw materials played a direct role in prehistoric tool makers' decisions to produce various types of stone tools.

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