The Study
of Technological Organization

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Archaeological research has increasingly turned to questions about the organization of behavior in all realms of culture. The specific questions asked and the units of analysis used depend on whether the focus is upon economic, social, political, ideological, or combinations of these aspects of cultural behavior. One branch of organizational studies that has developed during the 1980s focuses on the organization of technology. This is the study of the selection and integration of strategies for making, using, transporting, and discarding tools and the materials needed for their manufacture and maintenance. Studies of the organization of technology consider economic and social variables that influence those strategies.

One of the greatest contributions of studies of technological organization has been in emphasizing the dynamics of technological behavior. Dynamics refers to the plans or strategies that guide the technological component of human behavior. Understanding prehistoric land use is an especially common goal; technological plans are seen as responsive to resource conditions as well as economic and social strategies. Tool design and staging of manufacture, use, and reuse are suited to these technological plans. Thus, studies of technological organization expand our view of tool function to include variables of technological strategies.

Technological strategies weigh social and economic concerns with respect to environmental conditions and are implemented through design and activity distribution. Within this framework for technological organization, there are several levels of behavior that can be usefully distinguished for analytic purposes [Figure 2.1]. Most studies emphasize one of these realms over the others, but to discuss them coherently, I have arranged them in a hierarchy determined by
their distance from material implications. For example, the material implications of an economic strategy must be understood through the technological strategies that facilitate it, which in turn understand through the complex of designs or activity distributions best suited to that strategy. No one level of analysis identified in this figure is inherently superior to or more informative than any other. Ideally, research designed to understand the dynamics of the past would address all levels. However, the realities of research are that we focus on limited aspects of human behavior and attempt to contribute to the whole.

I have used the structure in Figure 2.1 to organize this chapter. In the first section, I discuss the environmental conditions and the social and economic strategies examined in studies of technological organization. In the second section, I define and discuss technological strategies. In the last two sections, I explore the designs and activity distributions that are implied by technological strategies, with emphasis on material implications. My focus is on stone tools and small-scale societies because these domains have received the greatest attention in studies of technological organization.

The product of this study is an outline of theory—systematically linked variables that must be controlled to predict specific outcomes—not a generalized model of behavior. The application of this framework in a given context depends as much on the character of the context as on the principles of technological organization.

The Notion of Strategy

Binford [1973, 1977] first used the concept of technology as strategy to understand variation across assemblages according to different uses of places and different plans. Koldehoff [1987:154] and Kelly [1988:717] offer definitions of technological organization that identify behavioral conditions for tool manufacture, use, maintenance, and discard beyond the specific task-performance requirements. Context and planning play a role in tool and toolkit design.

Strategies are viewed as problem-solving processes that are responsive to conditions created by the interoperability between humans and their environment (Binford 1973, 1977, 1978b, 1979; Bleed 1986; Gamble 1986; Kelly 1988; Koldehoff 1987; Parry and Kelly 1987; Shott 1986; Torrence 1983; Wiessner 1982, 1983). These conditions can be quite variable in time and space. Bleed and Bleed [1987:189] state that “environmental pressures interact with human behavior to favor some technological alternatives at the expense of others,” a perspective consistent with the natural selection model of evolutionary biology (Dunnell 1978a; Leonard and Jones 1987). Systems of strategies do not account for all technological behavior or all formal variation in tools, weapons, and facilities. Use of this approach, however, causes us to examine technology as a set of behaviors that contribute to human adaptation (Jochim 1981), rather than as a set of objects that are the products of human adaptation, an industry, or a production procedure (see Koldehoff 1987 for discussion of this distinction).

Technological organization is responsive to conditions of the environment including resource predictability, distribution, periodicity, productivity, mobility (Bangfort 1986; Binford 1978a, 1979, 1980; Bleed 1986; Gamble 1986; Kelly 1988; Nelson 1984; Shott 1986;
Torrence 1983), size and patchiness of resource areas (Binford 1977, 1980), and potential hazards (Binford 1977). Ecological studies of demography, social organization, and exchange, particularly those which apply optimality theory, consider the same variables (Foley 1985; Jochim 1979; Orlove 1980; Smith 1983; Winterhalder and Smith 1981; for a critique of optimal foraging theory, see Keene 1983). Humans are viewed as decision makers within a variable environment; ecological structure is viewed as conditioning behavior to some degree (Gamble 1986). Optimal or suitable choices among alternatives can be understood only within the context of environmental conditions and available technological capabilities.

For archaeologists, identification of the adaptive problems comes from assessing environmental conditions as they affect or are affected by human use of that environment. The problems are obstacles to achieving maximum return on investments of time and energy (Bleed 1986:738; Smith 1979:55; Torrence 1983) that are addressed by “rational strategies for problem solving” (Binford 1978a:453) within a given context. Problems include time stress (limitations on the time available to achieve a task—Gamble 1986; Smith 1979; Torrence 1983), energy costs (Bleed 1986; Bleed and Bleed 1987), mobility requirements (Binford 1978a, 1979; Gamble 1986; Kelly 1988; Nelson 1986; Short 1986; Torrence 1983), scheduling, risk management (Binford 1979; Gamble 1986; Wiessner 1982), social aggregation requirements (Jochim 1976), and raw material availability (Bamforth 1986; Gould and Sagers 1985; Kelly 1988). Problems must be weighed against one another with respect to different contexts. Bleed (1986), for example, identifies some hunting situations that combine these variables:

1. Hunting of animals that are continuously available but for which the specific capture location may be difficult to predict.
2. Hunting of animals that are available for short periods of time but for which the location and timing of potential capture are highly predictable.

“If humans are variably responsive to these factors, the relative success and stability of their adaptation will also vary” (Binford 1978a:453).

Again, there are ties to optimal foraging theory. Energy, time, and risk are among the major variables that are presumed to be managed and optimized in optimal foraging models (Smith 1983; Winterhalder and Smith 1981). I emphasize the term “models” because, as Foley (1985) aptly states, optimality models provide a basis for identifying options, advantages, and disadvantages against which behavior or, in the archaeological realm, inferred behavior can be evaluated and understood. In research on technological organization, optimization is not always an explicitly theoretical orientation. It is often not intended in a strict energy output-input sense (as seen, for example, in Winterhalder and Smith 1981); words like “suitable” or “appropriate” are often used (Binford 1978b; Nelson 1984).

This approach could be questioned at its foundation. Are there constraints to human adaptation? Do people strive to optimize their time, energy, and materials? With regard to the first question, there is no issue. Constraints are determined by the environment as well as by the levels or concepts of technological expertise and social interaction. The question of optimizing is more complex (Foley 1985; Keene 1983; Smith 1983; Winterhalder and Smith 1981). Rather than assuming that people achieve optimal solutions, I prefer to view optimizing as an important aspect of adaptation. People seek appropriate solutions to problems of adaptation, one problem being the acquisition of food and other natural resources. “Subsistence oriented decisions are goal oriented, and are made with definite expectations as to the nature of future conditions” (Binford 1979:261). We can model the constraints on acquiring resources and propose optimal technological solutions and their implications. Where these apply, we find optimizing in technological organization to be of major importance, where these apply weakly, optimizing along the dimensions modeled is not applicable or optimizing does not apply.

While economic strategies for dealing with environment are emphasized in studies of technological organization, a few studies include social strategies (Arnold 1987; Clark 1987; McNany 1989; Morrow 1987). One study stands out as an interesting example of consideration of social strategies in small-scale societies. Wiessner (1983) examines the effect of different social responses to risk on stylistic variation among the Kalahari San. Uncertainty about conditions of the physical environment is an important dimension of her model, different social relations that can prevent or reduce the effect of loss of resources are keys to understanding stylistic variation. Private storage, reciprocal partnerships, and collection of tribute for redistribution are among the social responses to risk.

Wiessner uses the term “style” in the sense employed by Wobst (1977) and Conkey (1978), referring to “formal variation in material...
Culture that transmits information about personal and social identity” [Wiessner 1983:256]. This contrasts with Dunnel’s (1978b:199) view of style as those forms which have no detectable selective value, those responsive to selective pressures are functional forms, a broadened view of function. Wiessner’s usage emphasizes the communication value of forms, but she states that stylistic variation “is subject to selection and may confer adaptive advantage on its users” [Wiessner 1983:256], placing her usage of the term “style” squarely in the functional category as defined by Dunnell. These distinctions are important to understanding studies of technological organization because in the former sense, style is an important design dimension that is poorly developed in this arena of study, while in the latter sense, style is not a consideration.

Planning and the Definition of Technological Strategies

Two strategies are most commonly recognized in studies of technological organization: curation and expediency. To these I add a third, opportunistic behavior, which I contrast with expediency. I should note that this tripartite categorization of technological strategies varies from the common distinction made between curation as planned and expediency as situational, opportunistic responses being subsumed within the latter [Binford 1979].

In an effort to synthesize the definition and utility of these concepts, it is important to emphasize that these concepts do not delimit a class of artifact or a type of assemblage. They identify kinds of plans for facilitating human uses of the environment that can be carried out in a variety of ways and are responsive to a variety of conditions. Artifact forms and assemblage composition are the consequences of different ways of implementing curation and expediency. This is a point to which I will return.

The term “curation,” introduced into studies of technological organization by Binford [1973, 1976], has been used and defined in many ways. Curation is a strategy of caring for tools and toolkits that can include advanced manufacture, transport, reshaping, and caching or storage. It need not include all of these dimensions, but a critical variable differentiating curation from expediency is preparation of raw materials in anticipation of inadequate conditions [materials, time, or facilities] for preparation at the time and place of use.

Curation might include preparing and carrying either cores or tools to a workplace. In the first instance, potential sources of tools have been curated; in the second instance, finished products have been curated. Subsequent changes in the forms of these objects depend on whether they continue to be part of a curation strategy or are used expeditiously. For example, stockpiled or transported cores facilitate a strategy of making tools as they are needed, an expedient strategy.

Curation has a continuous rather than a categorical effect on form [Shott 1989], varying with the conditions to which this strategy is responding. Curation mitigates the incongruity between availability of tools or raw materials and the location of tool-using activities [Bamforth 1986; Binford 1979; Keeley 1982; Parry and Kelly 1987; Sassaman 1984]. Additionally, curation solves the problem of acquiring mobile resources or responding to other kinds of time stress, such as short periods of availability of resources [Ebert 1986; Gamble 1986; Torrence 1983]. Time is invested in advance in order to maximize “capture” time.

Some argue that advance preparation of tools for transport to a use location (one kind of curation) involves high costs in manufacturing time that would be compensated by maintenance, reworking, and reuse [Binford 1977, 1979; Ebert 1979; Parry and Kelly 1987]. In contrast, Bamforth [1986] argues that maintenance of stone tools would occur only if material was not readily available. Both perspectives are concerned with efficient use of time, energy, and resources, but the former emphasizes time and energy cost in manufacture, the latter, time or energy cost in transport. However, regardless of how ubiquitous material may be, acquiring mobile resources continuously, as opposed to sporadically, necessitates the continuous availability of the associated toolkit. Under such circumstances, long-term curation of tools would be expected, a point that Bamforth recognizes.

Some definitions offered for curation have confused technological strategy with design. For example, Bamforth [1986:38], citing Binford [1973, 1977, 1979], states that curated tools are “effective for a variety of tasks” and “recycled to other tasks when no longer useful for the primary purpose.” The former is a versatile design and the latter is a flexible design [Nelson 1986; Shott 1986]. These designs are responsive to different conditions or strategies for using the environment.
not necessary definitional criteria for the curation concept. Maintaining a clear distinction between these levels may help us avoid definitional confusion and debate.

Expediency is the second technological strategy. Expediency refers to minimized technological effort under conditions where time and place of use are highly predictable [Bleed 1986; Nelson 1984; Parry and Kelly 1987]. While curation anticipates the need for materials and tools at use locations, expediency anticipates the presence of sufficient materials and time. Expedient technological behavior depends upon at least three conditions:

1. Planned stockpiling or caching of material, or anticipated placement of activities adjacent to raw materials [Bamforth 1986; Parry and Kelly 1987]
2. Availability of time to manufacture tools as part of the activity of their use—no time stress [Torrence 1983]
3. Long occupation or regular reuse of the place in order to take advantage of the stockpile or cache [Parry and Kelly 1987].

Disagreement exists about the costs and benefits of expedient technological strategies. Some argue that the costs of transporting raw material are high, while others argue that acquisition of raw materials is embedded in other activities and has no effective cost. Costs may vary with the relationship between strategies of land use and raw material distribution. Binford [1979] argues, on the basis of ethnographic observations, that acquiring raw material, caching, and stockpiling are strategies embedded in other activities. Materials are transported when people are moving for other reasons (e.g., seasonal shifts) and are acquired when people are monitoring or collecting other resources [Binford 1979:258]. Others agree, citing efficient use of time as a key to successful adaptation, especially in high-risk environments: no one comes home empty-handed [Gamble 1986; Torrence 1983]. But Bamforth [1986] argues that raw material procurement has a cost that must be considered. This disagreement is difficult to resolve because we have so few ethnographic examples of technologies that are dominated by stone [but see examples of stone acquisition behavior in Binford and O’Connell 1984; Gould and Sagers 1985; Nelson 1987b; and current debate on embeddedness of material acquisition in Binford 1979; Binford and Stone 1986; Gould 1978; Gould and Sagers 1985].

Expedient and curated plans can be interwoven, contributing to complexity of the eventual products in the archaeological record. For example, if an expediently manufactured item is discarded where it was initially made and used, it falls out of the behavioral system as an expedient product. However, if it is carried to another location after manufacture and use, it is incorporated into the curated toolkit. It will eventually drop out of the behavioral system as a product of an expedient strategy followed by a curated strategy, both influencing tool form. As a second example, the action of acquiring the stone and transporting it to a use location anticipates future needs. However, this stockpiling creates the opportunity for expedient manufacture; the stone could be shaped into a core and flakes removed when they are needed. Alternatively, the stone could be shaped into a core or tool in anticipation of future needs, thus again curation. It is crucial that curation and expediency not be perceived as mutually exclusive systems, but as planning options that suit different conditions within a set of adaptive strategies.

Some technological behavior is not planned; it is responsive to immediate, unanticipated conditions. This is opportunistic technological behavior [Binford 1979; Nelson 1984]. Immediate technological responses to some situations can produce unanticipated returns. Binford [1979] describes a situation in which Nunalmiut had shot several caribou encountered unexpectedly and had lost their knife. Available stone was broken for sharp flakes, and these were used for butchering. The hammer stone used to manufacture the flakes was made on the spot “of willow wood and part of old dog harness spreader” [Binford 1979:266]. Opportunistic designs and distributions are conditioned primarily by specific environmental and behavioral contexts, while designs from strategies of curation and expediency are conditioned by both the specific context and the broader context of planning.

Opportunistic responses have sometimes been referred to as situational because of the situational nature of manufacture and use [Binford 1979; Johnson 1987]. Use of this latter term is unfortunate because technological organization, in general, is a system of strategies for meeting situations or conditions. Some situations are anticipated or the uncertainty is anticipated (planned for in the design of the toolkit), and some conditions are unanticipated, responded to with whatever opportunity presents itself. Expedient (planned) strategies can be confused with opportunistic responses; in both cases tools are manufactured and used at the time and place needed, not in advance of need. This merging is unfortunate; opportunistic behavior
is not planned and, therefore, has different implications for design and distribution.

The various aspects of curation, expediency, and even opportunistic behavior have implications for the design and spatial distribution of tools and toolkits. These are examined in the following two sections.

**Design**

Design refers to conceptual variables of utility that condition the forms of tools and the composition of toolkits. Little attention has been paid to the causes and material implications of different design concepts (Bleed 1986; Schiffer and Skibo 1987; Shott 1986), with one exception. The suitability of the functional edge of a tool to perform the work required of it has received considerable attention in studies of edge shape and use-wear (e.g., Hayden 1979; Nelson 1981; Semenov 1964, Wilmans 1964, 1970). In this chapter, I consider five design variables: reliability, maintainability, transportability, flexibility, and versatility. These suit particular technological strategies. In this section, I define each design variable, its advantages and disadvantages, and material implications for tool form and toolkit composition. The advantages and disadvantages of these variables are considerations, either implicit or explicit, for emphasizing one variable over another in the manufacture and use of tools. None has universal priority over others except, perhaps, the minimal suitability of tool edge. How these variables are emphasized or deemphasized in a prehistoric context depends on the conditions and strategies appropriate to a context. Recognizing the application of different design variables in past contexts can help expand our knowledge of past technological strategies and may, perhaps, result in some prioritization of design variables.

**Reliability**

A reliable design always works when it is needed. It has sufficient parallel or substitute components that are dependable (Bleed 1986). Aspects of this dependability are overdesigned, strengthened parts, sturdy construction, and careful fitting of parts. Emergency replace-ments must be simple and standardized. Maintenance must occur in advance of use, not be integrated into the use time frame.

Reliable designs minimize interference with work time; maintenance and repair activities occur outside the use context. The manufacture time and materials needed to assure this dependability are costs of reliable design. Secure fittings and carefully designed parts require investments in time beyond what is minimally needed for a task. The overdesign aspect of manufacture means that materials are used that are perhaps stronger or better suited to the task than are minimally needed.

Bleed (1986) formulated this description from review of literature on design mechanics and applied it to hunting behavior. He argues that reliable systems are suited to a particular class of strategies for hunting large game, the encounter strategies. Scheduled encounter strategies have predictable hunting periods that are focused on specific game. The time and place are tightly structured, but the amount of pursuit and capture time is short (Binford 1978a: 85). Reliable systems allow that time to be used solely for getting the needed resource, the game. Unscheduled encounter hunting is a strategy for hunting specific game in predictable locations, but at variable times. Here pursuit and capture time are uncertain rather than short. Reliable systems allow hunters to take advantage of hunting opportunities at any time. Reliable designs, then, are best suited for achieving returns when there is a premium on resource capture and processing time. In hunting, this may occur with either unpredictable or short time frames, where location and game type are predictable.

Looking at ethnographic examples where these constraints apply, Bleed (1986) examines the technological strategies and finds evidence for the use of reliable systems. Eskimo hunt caribou by using a scheduled encounter strategy, employing a toolkit that is well prepared in advance, is sturdy, is constructed with good craftsmanship, and has redundant parts. He finds the same to be true for Eskimo winter seal hunting, where an unscheduled encounter strategy is employed.

Costs are incurred in materials, manufacture, and maintenance time toward the benefit of efficient tool-use time. Torrence (1983) emphasizes the importance of efficient use of search and pursuit time in high-risk environments, which is relevant to the Arctic (Binford 1978a) and, as Gamble (1986) has argued, to Paleolithic Europe as well. While reliable designs are suitable for maximizing tool-use
time, considerable downtime for manufacture and maintenance is needed both before and after tool use. Torrence (1983) argues that activities may be scheduled around the need for downtime (as in seasonal environments), but others argue that tool manufacture and repair are subsidiary to other activities or embedded in them (Binford 1978a, 1978b; Gamble 1986; Gould, Koster, and Sontz 1971).

Bleed (1986) states that the overdesign of the system, along with backup and parallel components, results in a heavy toolkit. Where this is the case, we might find that the strategy of caching, at least seasonally, is preferred over curated personal gear, which is transported from place to place (Binford 1979). The two toolkits that Bleed describes, for hunting caribou and for winter sealing, are extensively curated, but the Eskimo have excellent transportation systems, which minimize the cost of transportation (Binford 1977; Torrence 1983).

What are the specific material implications of reliable designing? Reliable designs cannot be recognized by specific artifact or assemblage types. However, some variables of form and reduction technique conform more closely to the demands of reliable designs than do others. Standardization of replacement parts can be achieved with a blade reduction technique (Arnold 1987; Clark 1987; Cowan 1987; Hoffman 1987). Blade cores can be made that yield products standard in outline and thickness. Although there is general agreement that blade manufacture is costly in material quality, training, and manufacture time (Clark 1987; Gamble 1986; Parry and Kelly 1987), the benefit of standardized replacement parts may outweigh these costs in some situations. There are different opinions about the portability of blade core technology (Clark 1987; Gamble 1986; Hoffman 1987), stemming perhaps from a focus on different blade production procedures, but reliable designs emphasize dependability, which may impinge on portability, depending on the complexity and weight of the designed form or toolkit.

Reliability is not the only advantage of blade technology, and therefore not the only predictor of the occurrence of blades archaeologically. Blade reduction is an excellent technique for conserving high-quality stone material. Once a core is shaped, nearly each flake removal produces a usable blade, which has a high ratio of usable edge to total material (Clark 1987; Hoffman 1987; MacDonald 1968; McNerney 1987; Morrow 1987; Parry and Kelly 1987; Sheets 1978). In addition, blades are standardized commodities, well suited to market exchange (Clark 1987). They can serve as markers of regional identity (Morrow 1987) because with high skill levels, tight control over form can be achieved. Perhaps the need for reliability in technological design led to initial developments of blade technology for use in time-stressed situations. Once developed or introduced in some settings, blade manufacture became tightly standardized through frequent or specialized manufacture. Blades would then be products of new kinds of strategies in more complex social systems—for example, as standardized trade goods or as ritual forms supplied for elite individuals.

Reliable designs also have secure fittings. In stone technology these may be found in the design of hafting elements. Mechanical analysis of the potential security of different haft designs for different tasks could lead to a better understanding of design reliability. Gamble (1986) suggests that an examination of breakage rates across point forms may be indicative of investment in design to protect against breakage. Kelly (1988) argues that small bifacial tools can be shaped for secure fitting in shafts. Shott (1986) notes that hafting elements in a highly curated, bifacial tool sample from a Paleo-Indian assemblage are larger than expected for the size of the tools. He argues that materials transported often and far should be lightweight, yet the hafts are larger than expected in comparison with hafted tools made from nontransported material. This anomaly may be a reliable design feature that served to make the transported tools resistant to breakage at the haft.

Finally, reliable designs are characterized by redundant functions that can be performed with different forms (backup components if the first form is ineffective). This may be seen in assemblages by the occurrence of standardization of haft form and size across various tool classes. It also may be seen in similar use-wear traces on formally different artifacts deposited in a similar work context. For example, a retouched knife firmly hafted to a wooden handle may break in use or prove to have an edge angle that is too broad for a task. This can be replaced with a sharp blade, struck from a core brought as backup. The retouched knife and the blade may have similar wear patterns. The blade may even be retouched to reshape the blade during use, but unless it is incorporated into the transported toolkit, it will be discarded at the site of use.

This way of backing up a reliable design may account for some of the patterning in tool form and discard seen by Cahen, Keeley,
and Van Noten (1979) in the Upper Paleolithic assemblage at Meer, although they argue that the discarding of retouched blades runs counter to notions about curation. Also, Odell (1981, 1988) reviews the shortcomings of many functional interpretations from morphological analysis of tools ranging from Mousterian assemblages to collections of projectile points from Illinois. He is concerned that single classes or types have different use-wear traces and that different tool classes have similar use-wear traces. The latter pattern may result from use of replacements in a reliable toolkit (as described above); the former may result from the use of versatile tool designs (multipurpose, as noted by Odell), which is taken up below. Expanding the notion of functional requirements in tool design to include reliability and other design variables contributes to understanding of the incongruity between morphological and use-wear data.

Maintainability, Versatility, and Flexibility

A maintainable design is made to work easily under a variety of circumstances (Bleed 1986, but see McGuire and Schiffer 1983 for a different definition with respect to architectural design). Both serial and modular designs serve this purpose. Serial design anticipates the order of various future tasks, changing form in a sequence; modular design permits any order to future tasks, employing replaceable working parts. Bleed offered as an example of maintainable design a machine used as drill, sander, and router.

Flexibility is another label commonly applied to this design alternative (Cannilli 1986; Goodyear 1989; Morrow 1987; Nelson 1986; Parry and Kelly 1987; Shott 1986). A flexible tool can be reshaped easily to meet a variety of needs. This definition differs from Shott's (1986:19), he defines flexibility with regard to the range of uses without reference to change in tool form. I distinguish two design strategies that have a range of uses: those which are changed in form to achieve multifunctional demands (flexible), and those which are maintained in a generalized form to meet a variety of needs (versatile). The modern multi-head screwdriver, which has replacement tips of different forms stored in the handle, is a flexible design. So is the Swiss army knife with many functional tips built into and stored in the knife handle. Both examples are tools of modular, flexible design. Bleed (1986) identified the !Kung hunting gear, Yanomamo hunting gear, and Eskimo summer caribou hunting gear as modular designs. Flexible designs may also be serial; examples are not as common in industrial-commercial technology, but serial reduction does occur in the regrinding of metal tool edges.

Maintainable design may be versatile instead of flexible. Versatile designs do not change form but can be used for a variety of purposes (Nelson 1986). My definition is similar to Shott's (1986:19); he defines versatility as the number of task applications to which a tool class could be applied (see also Ammerman and Feldman 1974). Shott measures versatility by the number of different functional edges per tool (or employable units, Knudson 1973). This is one way of achieving versatility; another is by employing generalized edge forms. The machete used by the highland Maya is a generalized, versatile form. The stone hupf used by the Seri for skinning, buttering, cutting, chopping, pounding, grinding, and scraping is a versatile, though simple, design (McGee 1895:239).

Maintainability is achieved at the cost of time invested in manufacture and in use. Reshaping and replacing modular units on flexibly designed tools competes with tool-use time. Using versatilely designed, generalized tools consumes more work time for many tasks than using edge forms specially tailored to the specific tasks. The advantage of both flexible and versatile design is in having a potentially wide range of tool-use options.

This advantage is important in situations where the specific timing and place of tool use is not consistently predictable and when exploitation of a range of activities and resources is anticipated. Hunting game that is continuously available, but on an unpredictable schedule (scattered but ubiquitous), is one such situation (Bleed 1986). Any activity that is not time-stressed, in Torrence's sense (1983), may be performed with a maintainable toolkit. Foraging in a diverse environment or one with little seasonal variation may be facilitated best with maintainably designed tools (Bleed 1986).

A second, equally important advantage of flexibility and versatility is the potential for simplification of tool assemblages. Shott (1986) demonstrates, through analysis of ethnographic data on foragers, that groups with high residential mobility must maintain limited tool inventories, necessitating use of some tool classes for multiple purposes.

What are the material implications of flexibility and versatility in tool and toolkit design? All design flexibility requires changing form through reworking and replacement as part of the use of the toolkit.
This implies the incorporation of simple repair kits in flexibly designed toolkits [Bleed 1986]. In prehistoric technologies these might include bone and stone hammers, prepared cores, and resin, among other items. Flexible sequential design requires somewhat generalized forms because specialized forms are difficult to shape to other forms. For example, once a drill is made, it is hard to change that drill into some other form (although as a replaceable part in a modular toolkit, this same drill facilitates flexibility differently, a point to which I will return).

The bifacial or disk core is often cited as a form with design flexibility [Binford 1979; Kelly 1988; Morrow 1987; Nelson 1986; Parry and Kelly 1987]. A variety of flake forms [for use as tools] can be produced from a bifacial or disk core as the core changes form through its reduction sequence (Binford 1979:262; Frison and Bradley 1980: 21; Morrow 1987:142; Parry and Kelly 1987). The toolkit comprised of a large biface core tool and its flake potential conforms well to Frison's (1974) description of the basic butchering toolkit for all contingencies: pounding/chopping tool with sharp cutting tool. Clark (1987:268) argues that blades are flexible forms. However, large-blade cores are not flexibly designed, because only one form can be made from them. In addition, the form of the core itself cannot vary to any great degree and cannot sustain edge damage through use as a tool if it is to continue to be used as a source of blades.

Sequential reduction, theoretically, should result in depositing or discarding a limited number of artifact forms: the end products of the sequence. However, tools will break and become flawed at various points in the sequence, resulting in deposition of a variety of forms in the archaeological record. In addition, if the sequence of forms is fairly regular, there should be a correlation between tool size and form. Perhaps some of the sequences of biface reduction identified in lithic studies [Bradley 1976:152; Granger 1973:18; Montet-White 1968:27, 28] are the products of maintainable, flexibly designed toolkits rather than of reduction series targeted at the final, small bifacial tool product. McAnany (1982) argues that sequential reduction of Classic Period bifaces in Mayan contexts in Belize represents conservation of a tightly controlled raw material, a situation equally amenable to sequential reduction but not related to design flexibility.

Modular, flexible designing has implications for tool and tool-kit form that are different from those of sequential flexible designing. Modules have interchangeable hafting elements with different functional ends [recall the Swiss army knife]. Modular flexibility in prehistoric context may be achieved by using replaceable foreshafts, each with different tips, or replaceable tools with the same hafting element form but with tip forms that are different or are of different material. Oswald's (1976) concept of technological complexity, defined by the number of techno-units or parts that comprise a tool, would classify tools of modular design as complex because they would have high techno-unit values. I should note that reliable designs, which have parallel and backup components, should also have high techno-unit counts and be identified as complex. Sequential, flexible designs and versatile designs, although they are also maintainable alternatives, would not be classified as complex in Oswald's scheme.

Versatility requires a generalized edge form or a tool form with several different functional edges. Again, the large biface can meet the generalized design features. The shape of a biface, or of flakes removed from it, may not conform in the most mechanically efficient way to a particular task, but such artifacts can be used for a wide variety of activities [Johnson 1987; Nelson 1986]. Within tool classes that represent versatile design, a variety of use-wear traces should occur because of the variety of tasks performed by tools in that class [Shott 1986]. Ahler (1971) identifies this pattern for projectile points from Roger's Shelter in Missouri. Perhaps these were versatile forms in the hunting strategies for which they were used. Tools designed to be versatile should have multiple functional edges with evidence of use-wear [Shott 1986]. These material implications of versatility are the sources of problems identified in the functional classification of forms with multiple edge use [Hayden 1979; Keeley 1974; Knudson 1973, 1979].

Transportability

The key aspect of transportable design is that the toolkit is carried to the task rather than made at the task location. The differential distribution of tool raw material in relation to tool-use locations necessitates transport [Binford 1979; Camilli 1983; Keeley 1982; Parry and Kelly 1987; Sassaman 1984; Shott 1986]. Transportable designs should not interfere with movement to the task location or with transporting other resources to residences or between residences.
To meet the constraints of mobility, transportable toolkits must be small (few items) and lightweight [Davis 1945; Ebert 1979; Gould 1969; Lee 1979:119; Most and Huntman 1982; Nelson 1986; Opler 1941; Shott 1986; Steyn 1971:320; Torrence 1983] and resistant to breakage [Schiffer and Skibo 1987].

Men’s gear among aboriginal Australians described by Gould [1969:76] exemplifies transportability. It includes clubs and throwing sticks worn in the belt, a wooden knife tucked in the hair, a grinding stone and spear thrower carried in the hand, and extra hooks for the spear thrower carried through a hole in the septum of the nose. This toolkit has few items, is lightweight, and is simple and versatile. These are not the only material items used; they simply constitute a transportable segment.

If the toolkit has few items, some of these must be either flexible or versatile in order to meet the variable contingencies of moving from place to place [Kelly 1988; Lee 1979; Shott 1986; Steyn 1971]. The Swiss army knife is, again, an appropriate example; it is portable and offers many task options. Other contemporary portable items have been modeled after the Swiss army knife: the “Mini-factory” with stapler, pen, paper cutter, staple remover, screwdriver, and scissors, and the “Mini-leatherman” with pliers, wire cutter, screwdriver, file, can and bottle opener, ruler, and knife. The “Mini-factory,” along with a few other items that can be carried in a briefcase, allows the mobile business person to perform office tasks anywhere.

If transportability is achieved by the use of a toolkit with few items, then conservation of those items may be expected. Items can be conserved by minimizing waste during reduction or reshaping and maximizing useful elements. Disk or bifacial cores maximize tool material; they provide a variety of flake forms for use as tools, yet these can be thin while having extensive, usable edge length [high edge-to-weight ratio] [Binford 1979; Bradley 1976; Goodyear 1989; Kelly and Todd 1988; MacDonald 1968; Morrow 1987]. In addition, the biface can be changed to a variety of forms and reshaped with minimal reduction of the stone; therefore, few need to be carried [Johnson 1987; Kelly 1988; Kelly and Todd 1988; Parry and Kelly 1987:298]. Waste flakes from tool manufacture should occur in low proportion on sites where transportable toolkits are used, while evidence of use and retouch should be in high proportion [Binford 1979].

Toolkits can be conserved by maximizing the use-life of tools and cores. The tools that are transported should be used extensively before replacement and discard, although replacing gear is determined by a variety of contingencies, of which mobility is only one [see Keeley 1982]. A preponderance of small reshaping flakes, a high index of thickness to length for a tool class, and the occurrence of especially steep retouch within a tool class are indicative of extended toolkit use-life. Serial tool design, which provides for long and variable use-life, would be well suited to transport. Some of the reduction sequences identified in North American Paleo-Indian assemblages [Goodyear 1988; Gramly 1984; MacDonald 1968; Wilmsen and Roberts 1978] may represent the use of serial design in transportable toolkits. Identification of bipolar reduction of small tool fragments in North American Paleo-Indian assemblages is an example of extensive use or “liquidation” of transported toolkits [Goodyear n.d., 1988; Gramly 1982; Kelly and Todd 1988; MacDonald 1968]; however, this pattern is determined also by the scarcity of material within the system overall [Goodyear n.d.; Hayden 1980; Kelly 1984].

Gamble [1986:288] notes the use of a special reshaping technique that extended the use-life of scrapers found in LaCotte cave on the island of Jersey. Employment of this technique correlates with rising sea level, which cut off access to local stone.

Goodyear [1989] argues that cryptocrystalline material is ideal for manufacturing portable tools because it is easily shaped to a variety of forms, can be reshaped with minimal waste, and provides sharp tool edges. The fracture of cryptocrystalline stone is more difficult to control because of the structure of the rock, resulting in more wasted attempts, less control of form, and less sharp, blockier flake forms than can be made from cryptocrystalline (chalcodony, chert, flint, jasper) and glasses (obsidian) [Lischka 1969; Semenov 1964; Speth 1972; Thomsen and Thomsen 1971]. The disadvantage of glasses for tool manufacture and use is that they are highly brittle (Lawn and Marshall 1979); a freshly manufactured tool edge is sharper than can be achieved on metal, but the obsidian edge dulls quickly and breaks easily.

Portable designs may be lightweight either because they are small [Ebert 1979; Most and Huntman 1982] or because they are made from lightweight materials. The “Mini-factory,” a package of small modules duplicating larger tools from transportable toolkits, exemplifies size reduction. Core weight can be reduced by careful preparation, ensuring that all waste has been removed while maintaining sufficient size for production of flakes [Binford 1979:262]. Shott [1986]
identifies a difference in width and thickness between unifaces of similar length in two Paleo-Indian assemblages representing different degrees of mobility. The thinner, narrower unifaces are in the highly curated, transported assemblage, which is “consistent with the expectation that the size of curated tools should be minimized to reduce carrying costs” [Shott 1986:37]. However, caution must be exercised in considering tool size as an index of portability. Tool size (not toolkit size) should not be evaluated without consideration of the extent of reduction of each tool, the materials from which tools were made, the tasks for which they were intended and used, and their organizational role in the technology.

Lightweight materials may be used instead of heavier, more durable materials in a transported toolkit. For example, baskets are lighter and less breakable than ceramic containers; for carrying items, we might expect to find baskets more often than ceramic pots in transportable toolkits. Wooden or bone tools might serve some of the functions otherwise performed by heavier stone tools. These organic tools, unfortunately, would be difficult to see archaeologically. Their manufacture and repair may be visible through use-wear analysis of stone tools.

In summary, transportable designs accommodate the constraints of mobility and anticipate future needs. The cost of acquiring appropriate materials (cryptocrystallines and lightweight materials, for example), manufacturing time (making tools that perhaps duplicate functions performed by less easily transported tools), maintenance time, and perhaps tool-use time are balanced by the necessity of having a usable tool in the right place at the right time. The specific function of a tool, in the task sense, may influence the form of the tool less than do the exigencies of transporting it.

The Effects of Material Availability—Conservation

Considerable debate has occurred over the effects of stone material availability on tool and toolkit design [Bamforth 1986; Binford 1979; Binford and Stone 1986; Gould 1978; Gould and Sengers 1985; Jelinek 1976]. To some extent, reduction techniques are responsive to availability of stone, and some core forms result from conservation. For example, disk cores result from conserving material using the Levallois technique [Bradley 1976]. Blade cores maximize or conserve material because a large quantity of tool edge can be produced in relation to amount of material [Clark 1987; Hoffman 1987; MacDonald 1968; McNerney 1987; Morrow 1987; Parry and Kelly 1987; Sheets and Muto 1972]. The same has been argued for bifacial cores (Clark 1987; MacDonald 1968; Parry and Kelly 1987).

Although a natural resource, stone is different from many other natural resources; at resource locales it is continuously available (in most cases) and not mobile, and is therefore easily manipulated. If raw material is unavailable, it is because humans have made social, economic, and technological decisions that create the condition. For example, they have settled at great distance from stone sources and have not stockpiled stone. I argue that such decisions affect tool and core design primarily, and that any resultant scarcity of material is secondary in conditioning maintenance and recycling. This position stands in contrast with Bamforth’s [1986], he places availability of stone material ahead of other conditioners of technological organization in his statement that maintenance and recycling are “closely related to raw material availability and not directly or solely to settlement organization or the time limits on the activities for which tools are used” [Bamforth 1986:40]. Bamforth argues that tools will be maintained and recycled only when raw material is in short supply, when it costs more to replace the tool than to rework it: “Why would anyone transport tools from place to place if raw material could be obtained everywhere?” [Bamforth 1986:40]. I share Bamforth’s concern with the availability of raw material, but only in the sense that stone tools or the materials to make them must be available where and when they are needed; there are many strategies for meeting this need.

Distribution

It is difficult to apply the above notions regarding design to archaeological contexts without some understanding of how technological organization influences the distribution and discard of tools and their manufacture debris [Binford 1980; Camilli 1983; Ebert 1986]. How are toolkits distributed archaeologically? “Toolkit” is a behavioral concept that has no necessarily associated construct in artifactual distribution [Ammerman and Feldman 1974; Ebert 1986; Jelinek 1976—but see Carr 1984; Whallon 1973]. Where are transportable tools made, and where are they discarded? What is
the effect of transport on tool distribution. These questions are clearly related to the design variables, but have often been dealt with as separate issues.

Artifact distributions are produced by items dropping out of the system through abandonment, loss, or discard, and by post-abandonment processes (Amerman and Feldman 1974; Ebert 1979; Schiffer 1972, 1976, 1987). This discussion excludes post-abandonment processes. Notions are presented about how planning and opportunistic technological behavior influence the location and staging of manufacture and use.

Many regional studies of technological organization use classes of sites as analytic units: base camps, residential sites, logistical camps, processing locations or extractive sites, lookouts (Binford 1976, 1978b, 1979, 1980; Camilli 1986; Custer 1987; Raab, Cande, and Stahl 1979). Others examine regional distributions without the site class or even the site as a unit of analysis (Ebert 1986; Kelly 1988; Nelson 1988; Nelson and Camilli 1984).

Most of these studies are of systems of adaptation that depend upon a fair amount of mobility. The specific distribitional patterns identified in studies described below should not be considered models applicable to any context where mobility is a consideration. Rather, the logic of the relationship between technological organization and distribution, and the premises upon which inferences are based, should be tested and applied with regard to context and in conjunction with other aspects of formation processes.

Site Function Inferences: Residences and Camps

Implicit in making distribitional generalizations from technological plans is that time to work on tool manufacture and repair is available at residences. In a system where curation is important, transportable tools should be manufactured at residences (Binford 1979b, Ebert 1986, Kelly 1988). Binford (1979), Torrence (1983), and Ebert (1986) argue that transportable tools will be brought back to residences to be maintained and reworked in order to recover the cost, in manufacturing time, of portable design. Bamforth (1986) argues that curated or transported tools will be returned to residences for repair only if raw material for making new tools is scarce. Bamforth’s argument perhaps applies mainly to nonhafted tools. For a hafted tool there are considerations of time invested in making a haft, removing a tool from a haft, and replacing it.

Time is not equally available at all kinds of residences. Those occupied during seasons of low productivity, sometimes described as downtime, should have the highest proportion of tool manufacture and repair debris because the greatest amount of time is available for these activities (Binford 1979, Gamble 1986, Gould et al. 1971; Keeley 1982; Torrence 1983). This assumes that occupants of off-season, or downtime, residences can live primarily from stored foods (Binford 1979, Torrence 1983).

Manufacturing and repairing tools at a residence implies the availability of raw material; this can be assured by settling near a source or accumulating material at a place that is occupied extensively or often (Binford 1979, Morrow 1987; Parry and Kelly 1987).

The material implications of these distributional products of curation for residences are varied. First, all stages of manufacturing debris, including primary reduction and core preparation, should occur at residences as the result of manufacturing and repairing tools and preparing cores to be used elsewhere (Binford 1977, 1979; Ebert 1986; Raab, Cande, and Stahl 1979; Thomas 1983). Second, expended tools and base segments from hafts should occur as they are removed and replaced with new parts (Binford 1977, 1979, Keeley 1982). Third, segments of tools broken in manufacture should occur at residences.

Repair may occur at camps for the same reason that it occurs at residences; camps have shorter occupation periods, often by segments of a resident group. The time available for repairs at camps is downtime between activities, not seasonal downtime. Again, for manufacture to occur, raw material must be available through natural availability, caching, or as part of the transported toolkit. Binford argues that in complex, logistical contexts, tool manufacture is staged such that partially finished items form part of the toolkit that is transported. These are worked at various places, including camps, when downtime permits (Binford 1979, Ebert 1986). Modification of transported tools by rejuvenation or by transformation into cores may be expected (Goodyear 1989) at camps, resulting in deposition of late-stage manufacturing debris in the absence of tools. Under this circumstance, the pattern of group movement may be evident from the distribution of stages of tool repair or transformation (Magne 1984, Raab, Cande, and Stahl 1979).
As noted, repairing and retooling requires raw material. Therefore, these activities may also occur at quarries (Keeley 1982). Kelly (1988:720) notes that the Pawnee hunters on the North American Plains apparently retooled at quarries. As at residences, materials should include all stages of manufacture, the bases of hafted tools, and tools broken in manufacture. The earliest stages of reduction should be more common at quarries than at residences, the result of initial testing and shaping of roughouts that are finished elsewhere (Callahan 1979; Ebert 1986; Nelson 1987).

Availability of time and availability of materials, the two assumptions about residences and camps that lead to expectations about manufacture and repair of curated toolkits, have other implications. Availability of materials also makes expedient tool manufacture possible (Gallagher 1977; Johnson 1987; Keeley 1982; Kelly 1988; Parry and Kelly 1987). Tools are manufactured when needed and discarded after use (Binford 1979). This process of concurrent manufacture, use, and discard results in the deposition of tools at the places where they are used (Binford 1977). The correlation of discard location and use location should occur only at places that are reused, where material can be stockpiled, and at locations where materials naturally occur. Some have argued that increased sedentism, spending greater and greater amounts of time in one place, leads to expediently planned technology because of the cumulative availability of material (Johnson 1987; Koldehoff 1987; Parry and Kelly 1987).

Three material implications may be recognized from these properties of technological expediency. The first is low investment in tool retouch. If expedient tools are made, used, and discarded where and when needed, the extent of shaping by retouch will be conditioned by the task at hand, not by planned maintenance or reuse. Unre- touched flakes and marginally retouched flakes are expected (Johnson 1987; Parry and Kelly 1987). The specific techniques of reduction may depend on the size and shape of material available for making tools and on the kinds of edges and handles needed (Hayden 1979; Nelson 1981; Wilmsen 1964, 1970), but should not reflect conservation, curation, or transportation concerns. If these latter become a concern, the plan is no longer technological expediency. Several different core reduction techniques may be used to produce tools expediently, or one core reduction technique that can result in a variety of flake shapes and sizes may be employed. A hand-held percussive technique with flake removals from multiple, nonopposing platforms produces a variety of shapes and sizes.

Morrow (1987) concludes that reduction of stockpiled material at Illinois Hopewellian residences employed a conserving strategy, a pattern not expected according to the statements made above. Blades, products of efforts to conserve material and/or to obtain standardized products, were manufactured from stockpiled high-quality chert and were used locally. Morrow argues that a conserving strategy had no economic value in this context. Instead, the standardized aspect of blade products is seen as consistent with a pattern of manufacture of other items that emphasized standardized markers of regional identity. Uniformity was sought during this Middle Woodland period, as a marker of participation in developing networks of social relations (Braun 1986; Morrow 1987). Blade manufacture was conditioned by this social context; expediency was expected from settlement and material availability conditions, but social context was seen as intervening. It is interesting that in this study, Morrow carefully evaluates the direct economic or ecological-functional advantage of blade manufacture before turning to the social context.

Returning to technological expediency, a second material implication can be understood by recalling the distinction that I made between technological expediency and technological-opportunistic behavior. Opportunistic behavior is a response to the unanticipated, technological expediency is a plan made possible by adequate supplies of raw material that favors minimizing the cost of tool manufacture under conditions where material, time, and mobility are not major concerns. In an assemblage produced by technological expediency, some core preparation should be expected because the cores serve as stockpiled material to be used later. This may occur at residences and camps. In a collection resulting from opportunistic behavior, no core preparation may occur because continued use of the place may not be anticipated in most cases. In other words, opportunistic behavior should occur rarely at residences and camps because a supply of usable raw material and tools is available.

A third material implication of expediency is that cores of different stages of reduction should occur at camps and residences. The cores form part of the stockpile of raw material, and, because they are not part of the transportable toolkit, should be discarded at the place of their reduction (Nelson 1988).
Some have argued that technological expediency results in a regular relationship between the amount of work done and the number of tools deposited, and between the amount of debris produced and the number of tools used, because tools are made, used, and discarded in the same place [Binford 1977; Custer 1987]. This may be true of deposits formed solely by expediency. At residences, however, the curated toolkits are manufactured and repaired, leaving a variety of debris. Also, the debris from tool manufacture and repair at one point in time may become the stockpile of usable material at a later time, further complicating expectations about assemblage composition.

Another implicit principle applied to identification of residences or camps is that length of occupation and regularity of reoccupation condition storage and reuse. Storage at residences is referred to as stockpiling [Binford 1979; Morrow 1987; Parry and Kelly 1987] at camps it is often referred to as caching [Binford 1979; Ebert 1986]. In either case, some refer to the stored materials and tools as site furniture [Binford 1978b; Camilli 1983, 1986; Ebert 1986; Nelson 1988]. Items that are too complex or heavy to be moved from place to place may be site furniture. The construction requirements of reliable design [strengthened parts, sturdy overdesign, extra components] may result in heavy, complex tools that become site furniture. Metates are costly to transport because they are heavy. Less heavy items, such as cores and hammer stones, may be stockpiled or cached.

All stages of reduction of site furniture, from newly manufactured to expended forms, should occur at residences and camps because the items are not often transported from the site where they were first used. They are brought up for use from the stockpile or background of debris on the site. Binford [1979] notes that the size effect—larger average artifact size on and near the surface of the site than in more deeply buried deposits [House and Schiffer 1975:174-75]—may result from regular use and reuse of site furniture. Baker [1978] also notes the importance of reuse as a factor contributing to the size effect.

Site Function Inferences: Limited Activity Sites

In contrast with residences, we often assume that little time is available for tool manufacture at “special-activity” or “extractive” sites. Activity is focused narrowly on performing tasks that can be done most efficiently or effectively in that place. Processing [e.g., butchering an animal or roasting agave] may be done away from the residence for several reasons: the cost of transporting unprocessed material is high, the large amount of processing interferes with other activities at the residence, and the processed material is to be consumed “in the field.” The reasons depend on the organization of strategies, and the results are scatters of artifacts from a narrower range of activities than would be found at residences [Binford and Binford 1966; Camilli 1983, 1986; Raab, Cande, and Stahl 1979].

If tools are not regularly made on special sites, they must be transported to them. There are two technological implications. First, debris will be primarily retouch flakes from sharpening transported tools [Ebert 1986], as at a kill and butchering site described by Frison [1968]. Second, tips from hafted tools and segments from hand-held tools that break and are not salvaged for the transported toolkit should be discarded at the site [Ebert 1986; Raab, Cande, and Stahl 1979]. The form of these tips will depend on the design demands and stage of reduction or life history of the toolkit [Camilli 1983, 1986]. If the transported toolkit is designed with sequential flexibility, its composition will change over time. However, if it is designed with modular flexibility, the module that breaks may be different from one special-use site to the next. For these reasons, the forms of tool fragments deposited on special-use sites will be highly variable among those sites as a class [Binford 1977; Camilli 1983, 1986; Gamble 1986].

Cores also may comprise part of a toolkit transported to a special-use site. Recall that bifacial core/tools and blade cores may be transported, the former as flexible sources of flakes for use as tools and the latter as sources of standard flake forms. Flake manufacture takes essentially no time, if the cores are prepared in advance and carried to the special-use site. If this technological strategy was involved, the flake debris on the site should not include debris from primary core reduction. In addition, a high proportion of flakes should have utilized edges [Johnson 1987] (excluding the flakes resulting from retouching tool edges) and the flakes, as a group, should be fairly homogeneous in form, reflecting a portion of the bifacial reduction sequence (see Callahan 1979 for one example of these flake forms) or the blade-core reduction sequence (see Crabtree 1969 for one example).

Debris from curated, transported toolkits may dominate the material at special-use sites. However, technological expediency should
occur where raw materials and time to make tools are available [Ebert 1986], and when knowledge of this availability is built into the technological plan (i.e., the place is regularly reused).

Opportunistic technological behavior is expected to a greater degree at places that are not reused regularly because of the complex contingencies of being in a place only rarely. The material implications of opportunistic behavior are difficult to predict because they are based on situational contingencies of the moment and on the condition of the toolkit or raw materials immediately available; they should be highly variable from one context to another (Binford 1979). Because opportunistic behavior has no prior planning and no product for future use, little effort should be invested in design or preparation (Binford 1979:267). Minimally effective products should be expected. Isaac (1986) suggests that opportunistic products lack pronounced orientation and have irregular edges and spurs. However, he is discussing Oldowan tool assemblages, which may not be an appropriate analogue for more recent prehistoric technology.

Some Comments on the Site-Type Approach

Approaches to the organization of technological behavior have become inextricably linked to settlement models, to some extent because of Binford's contributions to technological and settlement models through analysis of his Nunamiut and Alyawara data. The strategies of land use described as collector (logistical) and forager have been transformed into settlement types with accompanying site types. Although this paper focuses on technological organization, a brief assessment of the analytic use of settlement types is necessary to clarify the utility of distributional considerations of technology.

Types are associations of variables resulting from patterned behavior [Spaulding 1973, 1977]; it is the behavior behind the patterns, not the types themselves, that is important. Typological analysis allows us to identify and describe relationships in specific contexts. To reify the types as universally applicable labels is to lose the context, to lay constructs over behavioral remains where they may not be appropriate.

Using an approach that focuses on site types has many limitations. First, an obvious, but important, statement to bear in mind: We depend upon the reality that the organization of systems varies across space and changes through time. Strategies are mixed and differentially emphasized in many ways. For example, foragers may occasionally employ logistical strategies in a particular setting or with respect to a particular resource. The amount of movement by task groups will influence the contribution that portable toolkits make to the debris of residential assemblages. The regularity and timing of site reuse will influence the condition of site furniture. Therefore, generalized associations of artifact classes used to define standard site types, thought to exist as a generalized typology of settlement behavior for all contexts, will not contribute to our understanding of human behavior.

Second, the characteristics of particular site types in one region will not necessarily apply to any other region. Instead, it is the principles that condition the patterning identified in site types which may be applied broadly. For example, there are material implications for the principle that time stress in hunting requires advance preparation of toolkits at residential and camp locations where downtime is available. We should focus on testing these kinds of principles. Fitting descriptions of activities at residences or camps from ethnographic observations to archaeological data is only a preliminary heuristic step. Although such a criticism may seem unnecessary, the use of site types from ethnographic descriptions as analogues is common.

Third, the conditioners of site formation are incredibly complex (Binford 1980; Camilli 1983; Schiffer 1972, 1976, 1987) and must involve consideration of variables other than human strategies. For this reason, the search for site types based on strategies of land use can be fruitless. Where combinations of strategies recur and post-depositional effects are similar, site types may be identified within a region (see Camilli 1983). All too often, however, the type is an ideal to which reality is only approximate. Polythetic descriptions of artifact types were responses to this reality in typological analysis (Thomas 1976).

Logistics and foraging are two strategies of land use that are governed by principles of organization. Binford identified some of these and their material implications, and illustrated them with specific ethnographic data. Applying the principles of these strategies to understanding the distribution of material remains will prove more fruitful for our understanding of human behavior than will searching for the same kinds of sites described in the Nunamiut data. The
former, I believe, was the intent of the original presentation of the logistical and foraging models.

Other Regional Approaches

Some research on technological organization addresses patterning in the distribution of technological strategies on a regional scale that does not proceed from the identification of site types. The artifact or artifact class is the analytic unit of comparison. Distributional expectations refer to regional patterning of artifact classes, not the characteristics of different places. Some studies employ data recorded in site clusters (Kelly 1988; Nelson 1986, 1988, 1990; Nelson and Camilli 1984); others reject the heuristic value of "site" for some kinds of research questions (Dunnell and Dancey 1983; Ebert 1986; Thomas 1975).

I briefly mention three examples of these studies assessing how aspects of technological strategies were employed regionally. Kelly (1988) examines the regional distribution of different kinds of bifaces on sites in the Carson Sink and surrounding mountains of Nevada in order to understand changing land-use patterns. He argues that large bifaces were usable as cores in a transported toolkit. Distribution of the stages of biface reduction is examined as evidence of mobility. The occurrence of bifacially produced flakes as isolates on the valley floor, in contrast with their occurrence in artifact clusters (sites) in the mountains, is identified as possible evidence for logistical mobility on the valley floor and residential mobility in the mountains.

Two of my recent analyses of stone technology in southern New Mexico employed this approach, using data that were recorded in site clusters (Nelson and Camilli 1984). The logic of the analysis is that technological plans should vary across different resource and topographic features. Areas used or occupied repeatedly or regularly allow technological expediency to be employed in task performance, except where frequency of movement is high. The more often people moved in using any particular area, the greater the evidence of curation in artifact assemblages from that area, supplemented by products of opportunistic responses to unanticipated situations. I have discussed above some material consequences of these different strategies; on a regional scale, the distribution of items is examined by resource zones and topographic features. For example, I find little evidence for reuse of rockshelters in the mountain areas along the eastern slope of the Black Range, indicating that these kinds of features may not have served as focal points for prehistoric exploitation of mountain resources.

Ebert (1986) explores regional distributions without the heuristic category "site." Varying the scale of analysis, he identifies similar scales or patterning for debris and utilized flakes, products of expedient strategies. This pattern varies by stone material; the local quartzites are distributed differently than are the exotic cherts. Ebert attributes the pattern to differences in source; expediently used exotic cherts were recycled pieces of the transported toolkit, expediently used quartzites were locally acquired. Expedient reduction of exotic cherts, therefore, could have occurred only where items of chert had fallen out of the transported toolkit. This is only one aspect of Ebert's study, which is an excellent comparative analysis of site and nonsite data employed in distribitional studies of consequences of technological strategies.

Implication and Future Directions

Glynn Isaac [1986:237] has said that in order to understand past adaptations in ways that are more than reflections of ourselves, we must integrate "a knowledge of ecology and an understanding of alternative strategies for exploiting the economy of nature." Studies of technological organization emphasize the importance of considering strategies, particularly strategies for dealing with conditions of the physical environment. Various kinds of residential and nonresidential mobility, resource selection, and activity scheduling have been investigated through recognition and analysis of technological strategies. The vast literature on cultural ecology and human mobility has not been given systematic attention in this chapter. Instead, I have briefly summarized the ecological variables and approaches taken in research on technological organization. I have then discussed what technological strategies have been considered, how these might be implemented through tool and toolkit design and through activity distribution, and, finally, how these may be recognized in the form and distribution of material culture.

Technological strategies are not fixed "types" of behavior, so they cannot be said always to occur under specific circumstances or to have consistent formal or distributinal implications. These stra-
gies are plans that involve juggling variables of the natural and social environment, and the range of cultural options [social, political, ideological, technological]. The need to acquire resources in different locations, to move around the landscape, to remain settled at a place, to transport different kinds of resources and material needs, and many other variables condition the technological strategies employed at a particular time and place. Curation, for example, may be employed more or less extensively, different kinds of items may be curated, and various aspects of curation [transport, reuse] may be emphasized, depending on how economic and social concerns are prioritized. In this area, studies of technological organization are especially weak. I think the strength of future research lies in ways of understanding the decision process under a variety of social and environmental conditions. If we ignore the role of technological strategies because our understanding is incomplete, we narrow our vision of how humans adapt to natural and social conditions.

To integrate technological organization into an understanding of past adaptations, we must begin by enumerating the conditions [natural, social, cultural] that constrain human behavior within a given time-space framework. We must then evaluate the range of strategies for living within these conditions and how the selection of strategies varies. Technology facilitates, and perhaps also constrains, much human activity, particularly human relations to the natural environment. Thus, through analysis of technological organization we can recognize adaptive strategies and understand their change in relation to adaptive constraints.

Little attention has been paid to the relationship among technological organization, social conditions, and social strategies, although there are a few provocative examples [McAnany 1989; Morrow 1987; Wiessner 1983]. Interest in how technological strategies facilitate social strategies of individualization, family integration, reciprocity, territorial interaction, and territorial flexibility would benefit our understanding of technological organization. Implications for design and activity distribution depend on how information is communicated and how controls are implemented and maintained. I believe that the aspects of style, as defined by Wobst [1977] and others [e.g., Wiessner 1983], that can be assessed as functional in Dunnell’s [1978b] sense [that offer potential selective advantage] are the only aspects that can be addressed through models of technological organiz.

ization. In the current climate of interest in information exchange, the social aspect of technological organization should be filled out.

Thus far, I have focused attention on abstract concerns of an anthropological archaeology. However, we often are also faced with empirical questions about formal or distributional variation within artifact assemblages. Why are tools with the same use-wear traces so diverse in form? Why are some core forms reduced to small, spent size while others are discarded or abandoned with considerable flake potential remaining? Why do tools with different functional ends have the same haft form? These questions can be addressed by examination of the implications for design and activity distribution, understood through the framework of technological strategies.

Our knowledge about the material implications of design can be enhanced in two ways. First, knowledge generated in other fields can strengthen our understanding of design. Use-wear analysts have sought information from physics and engineering [e.g., Hayden 1979]. Psychology, design engineering, and architecture are potential fields of study that could contribute to our understanding of the conditioners of design variables, as well as the potential advantages and disadvantages of design alternatives. Within our own field, experimental studies have expanded from tool replication and use-wear to assessment of physical properties relevant to transport and other performance characteristics [e.g., Schiffer and Skibo 1987]. Second, understanding and identifying the roles of items other than stone tools in the organization of technology can enhance our knowledge about technological strategies. For example, the design of vessels should vary with the amount that they are moved. Schiffer and Skibo [1987] argue that selection of temper for manufacture of ceramic vessels in the North American Late Archaic was conditioned by mobility [but see Goodyear 1988]. Some data on ceramic and bone artifacts could be incorporated in studies of prehistoric technological organization.

Related to this concern is the caution that no single variable or set of variables for one class of artifacts can be used alone to make inferences about past behavior. There are two reasons for this caution. First, the material implications of design and distributional responses to technological strategies can result from a variety of other conditioners. As I noted at the outset, technological strategies are only one class of conditioners of the archaeological record. Second, the sources from which we model past technological strategies and
their implications are ethnographic, experimental, and mechanical studies in which stone is rarely the dominant medium. We must translate the principles identified through this modeling process to the media of the past. For both reasons, independent lines of evidence are needed to support inferences about behavior made from stone material remains [see Kelly 1988], a comment applicable to archaeological research in general [Wiessner 1982].

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Water Management Adaptations in Nonindustrial Complex Societies: An Archaeological Perspective

VERNON L. SCARBOROUGH

Land management unites the household; water management unites the community.
—Beardsley et al. 1959, p. 126

Water management is the interruption and redirection of the natural movement or collection of water by society. It is a topic that most archaeologists are forced to address whether in the acquisition of field data or in the preparation of a broad theoretical treatise. The following presentation will review and assess the many ways in which water is manipulated by society. The chapter is organized into five parts: (1) physical properties, (2) water management techniques, (3) social costs of water management, (4) archaeological case studies, and (5) conclusions.

My purpose is to evaluate the significance of water management by examining salient aspects of several nonindustrial complex societies. This is not another attempt to critique Wittfogel's Oriental Despotism; it is, rather, a broad-based literature review canvassing old and new finds and interpretations associated with the manipulation of water. Generally the examples draw from primary state centers of sociopolitical development, though less complex cases are examined. The chapter provides a methodological framework for interpreting the variability in these water systems.

The presentation covers a range of human variability in the manipulation of water and emphasizes the various methodological and theoretical points developed in the "Social Cost" section and the "Archaeology Case Studies" section. In order to assess the environmental and social forces that facilitate adaptation, early techniques...