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American Antiquity, Vol. 48, No. 4. (Oct., 1983), pp. 675-706.

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Research in experimental archaeology, ethnoarchaeology, geoarchaeology, and vertebrate taphonomy has appreciably increased our general understanding of the formation processes—cultural and natural—of archaeological sites. In synthesizing some of these recent advances, this paper focuses on the traces of artifacts and characteristics of deposits that can be used to identify the formation processes of specific deposits. These observational phenomena are grouped into three basic categories that structure the presentation: (1) simple properties of artifacts, (2) complex properties of artifacts, and (3) other properties of deposits. Also considered is the way in which prior knowledge can help the archaeologist to cope with the large number of processes and the nearly infinite combination of them that may have contributed to the specific deposits of interest. Several analytical strategies are proposed: (1) hypothesis testing, (2) multivariate analysis, and (3) use of published data to evaluate formation processes. This paper demonstrates that the identification of formation processes, which must precede behavioral inference and be accomplished by any research endeavor that uses evidence from the archaeological record, can become practical and routine.

DURING THE PAST DECADE, archaeological research on formation processes, a subject of traditional but desultory interest (e.g., Green 1961a, 1961b), has burgeoned along experimental, ethnoarchaeological, and theoretical lines (Schiffer 1978a). Despite this growth in knowledge, recent advances in the study of formation processes have only rarely been incorporated into the recovery, analysis, and inference stages of investigations. Indeed, in no other area of archaeological methodology is there a greater disjunction between theory and practice. In an effort to remedy this situation, the present paper briefly explores several general issues concerning formation processes, addressing at length the most pressing of these: the development of criteria for empirically identifying specific processes. I aim to show that, on the basis of extant information, the rigorous investigation of formation processes—in any project—can be practical. It is essential that studies of formation processes come to be conducted routinely; for unless the genesis of deposits is understood, one cannot infer the behaviors of interest from artifact patterns in those deposits.

BACKGROUND

With the advent of settlement and processual studies in the 1950s and 1960s, a high priority was placed on extracting from archaeological remains as much social and behavioral information as possible. The arbitrary strictures that confined archaeological inference or that ranked inferences on a scale of inherent difficulty (Smith 1955; MacWhite 1956) were rejected (Binford 1962, 1968). The basis of this reorientation is the far-reaching claim that because cultures are systems consisting of interrelated components, their "transitory" parts (e.g., ideology and social organization) are reflected in the often preservable material parts found in the archaeological record (Binford 1962, 1968). A more operational version of this principle was framed in terms of "pattern": human behavior is patterned and so are artifacts, thus the archaeological record is patterned (e.g., Hill 1970:15). This particular formulation was especially appropriate for justifying the use of "pattern discovery" analytical techniques.

Unfortunately, as researchers began pointing out almost immediately, this basic methodological principle is simplistic. It was shown by theory (Cowgill 1970; Schiffer 1972) and by ethnoar-

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0002-7316/83/040675-32$3.70/1

chaeology (e.g., Ascher 1968; Heider 1967) that the material traces of the sought-after organizational patterns could be disturbed and new patterns created by diverse processes of humans and nature (see also Krause and Thorne [1971] and Wilcox [1975]). Formation processes, cultural and noncultural (or natural), create the evidence of past societies and environments that remains for the archaeologist to study (Schiffer 1972, 1976, 1977; Schiffer and Rathje 1973). (For a brief introduction to the major types of formation processes, see Rathje and Schiffer [1982: 105–153].)

The countercurrent of concern with formation processes in the late 1960s developed in the 1970s and early 1980s into a multifaceted research effort. Not only have ethnoarchaeological and experimental studies furnished new insights, but the nature of archaeological inference has been reexamined and clarified. Although the unbounded enthusiasm of the new archaeology for directly interpreting archaeological patterns behaviorally has been moderated, there is still ample cause to be optimistic about the inferential potential of archaeological evidence (e.g., McGuire 1983).

The new synthesis on inference goes roughly as follows. Material culture, as the new archaeologists claimed, does pervade the operation of human societies. Indeed, artifacts do not just reflect behavior and organization, they actively structure social interaction (Hodder 1982), participate intimately in most activities (Rathje and Schiffer 1982), and influence the course of social change (Rathje 1979). From the standpoint of inference, then, the behavioral and organizational properties that interest archaeologists are reflected—sometimes redundantly and often in complex or subtle ways—in artifacts. However, except in ethnoarchaeological settings and modern material culture studies, we do not deal with items in systemic context. Artifacts recovered archaeologically have been deposited by adaptive systems and subjected to other cultural and natural processes (Ascher 1968; Schiffer 1975a, 1975b). Thus, in order to infer the *systemic* properties of interest, the archaeologist must identify *and take into account* these formation processes. This abstract schema is subscribed to in one form or another by many contemporary theorists and methodologists (e.g., Binford 1981b; Butzer 1982; Clarke and Chapman 1978; Dean 1978; South 1977; Thomas 1979).

The emerging consensus on the need to treat formation processes in all inference does not, regrettably, extend to details about how those treatments are to be effected. Synthesis is as yet incomplete in several important areas: (1) how best to conceptualize the nature and operation of formation processes, (2) how to assess their influence on the evidence of the past, and (3) how to identify empirically which formation processes created specific deposits. I now briefly examine several major conceptions of formation processes in order to establish the rudiments of a coherent framework for dealing with (1) and (2). The remainder of this paper tackles (3).

Some Conceptions of Formation Processes

The foundations of the "entropy" view were elegantly articulated by Ascher (1968) in one of the first general treatments of formation processes. He suggested that "time's arrow" progressively reduced the quantity and quality of evidence surviving in the archaeological record. The entropy view implies that our potential knowledge of the past is directly related to the state of preservation, which is conditioned by the time elapsed since cultural deposition. In deposits laid down recently, more can be learned about the past than can be learned much later when fewer artifacts—and those probably disturbed—are left. Although this position is unassailable as a statistical generalization, it has three important general exceptions. (1) Because degradation is caused by specific processes—not the passage of time per se—deposits laid down at the same time, but subjected to different formation processes, vary in their degree of entropy. Therefore, deposits must be evaluated for their information potential (or limitations) on a case-by-case basis. (2) Even in badly degraded deposits some inferences—often very significant inferences—can be made confidently. Although Ascher himself did not utterly rule out the possibility of making such inferences, present-day adherents of the entropy view, especially in cultural resource management studies, have drawn this implication and sometimes "write off" heavily disturbed sites. (3) Important materials, known as ecofacts (Shackley 1981), accumulate in the archaeological record through natural processes; such items serve as evidence for paleoenvironmental reconstruction, for inferring which noncultural formation processes acted on a deposit (Gifford 1981), and for comparing the relative contributions of cultural and noncultural deposition (Brieur 1977). Thus, some information of archaeological interest accumulates through time (Sullivan 1978; Gladfelter 1981:349). Despite its intuitive appeal, the entropy view takes us only part way toward understanding the general features of formation processes. However, Ascher performed an important service by calling attention to formation processes and the need to take them into account in inference.

In 1970 Cowgill built a conception of formation processes predicated on the idea of statistical sampling. He pointed out that one had to recognize the discontinuities between three basic populations of interest to archaeologists: (1) events in a past behavioral system, (2) the artifacts created and deposited by that system (the "physical consequences" population), and (3) artifacts that remain and are found by the archaeologist (the "physical finds" population). Regarding the relationships between the latter two populations, Cowgill (1970:163) noted,

> a physical consequences population is completely determined by the activities of some ancient people. Physical finds populations depend on ancient human activities, but also on subsequent events, human and non-human, and on the techniques, concepts, and equipment of investigators.

By stressing the discontinuities in populations, Cowgill set the stage for viewing formation processes as agents of bias within a sampling framework.

The most explicit and detailed statement of the "sampling bias" view was offered by Collins (1975). He recognized more populations than Cowgill, and stressed not just the reduction in the number of artifacts from one population to the next, but the likelihood that formation processes acted selectively. Each population, then, was a potentially biased sample drawn from the previous population that was itself a potentially biased sample: "We may view these discontinuities as sampling biases in the sense that what we recover and observe does not proportionately represent each aspect of the antecedent behavior" (Collins 1975:29). A growing number of ethnoarchaeological studies dramatically supported the claim that formation processes, especially site abandonment and decay of organic materials, create a biased record of artifacts in past societies (e.g., Bonnichsen 1973; David 1971; Lange and Rydberg 1972; Robbins 1973; Stanislawski 1969). In vertebrate taphonomy, as well, many actualistic studies buttressed the sampling bias view (e.g., Behrensmeyer and Hill 1980; Brain 1981; Gifford 1981; Shipman 1981); indeed, taphonomic processes themselves are often referred to as "biases" (e.g., Brain 1981:7; Gilbert and Singer 1982). The sampling bias conception, although suffering from some of the same limitations as the entropy view, was a step forward because it tacitly recognized that formation processes work in patterned ways.

Another conception of formation processes developing in the 1970s can be called the "transformation" position. Drawing on the insights furnished by Ascher, several investigators argued that, as a result of formation processes, the archaeological record is a transformed or distorted view of artifacts as they once participated in a behavioral system (Reid et al. 1975; Schiffer 1972, 1976, 1977; Schiffer and Rathje 1973). This conception explicitly embraced the spatial dimension of cultural behavior and archaeological remains, stressing the diverse processes that transform or distort materials, and the many ways they do so: formally, spatially, quantitatively, and relationally (Rathje and Schiffer 1982; Schiffer 1976, 1978b; Schiffer and Rathje 1973). The basic practical implication of the transformation view is quite simple: regardless of how much evidence is present, the archaeologist cannot read behavior and organization directly from patterns discovered in the archaeological record. However, because formation processes themselves exhibit patterning (the "biases" of Collins [1975]), the distortions can be rectified by using appropriate analytic and inferential tools built upon our knowledge of the laws governing these processes (e.g., Schiffer 1976:12).

The transformation view and other modern conceptions of formation processes recognize a basis for the traditional belief in the limitations of archaeological inference. These limitations, however, are not general, but are specific to deposit, site or region, and are determined by the formation processes that created the deposits (Reid et al. 1975). Needless to say, limitations can only be specified with reference to given research problems (cf. Binford 1981a:200).

In concluding this discussion of the transformation view, I note that it is at odds with the entropy conception in one important respect: formation processes do not just degrade artifacts, they can introduce patterning of their own (Binford 1978a; Schiffer 1976; Sullivan 1978; Wilk and Schiffer 1979; Wood and Johnson 1978). In addition, the sampling bias and transformation views are compatible. To note that a formation process has a biasing effect is also to acknowledge that it has predictable consequences—which can be described by laws. The bodies of theory identified by Clarke (1973) express a similar belief in the nomothetic nature of formation processes.

Recent work in taphonomy, geoarchaeology, ethnoarchaeology, and experimental archaeology supports the principal tenets of the transformation view. It has been shown that formation processes (1) transform items formally, spatially, quantitatively, and relationally, (2) can create artifact patterns unrelated to the past behaviors of interest, and (3) exhibit regularities that can be expressed as (usually statistical) laws. Specific findings of these studies form the basis of later sections of this paper.

Following development of the transformation view, various attempts were made to show how the effects of formation processes could be modeled and taken into account in the course of making inferences to answer research questions. Although an examination of "transformation models" would be out of place here (for general and specific examples see Fedele [1976], Kirkby and Kirkby [1976], Reid et al. [1975], Reid [1982], Rock [1975], and Schiffer [1975a, 1975c, 1976]), some general points arising from these efforts need to be mentioned. In the first place, formation processes introduce variability into the archaeological record: patterns are destroyed or modified, new patterns are created; materials are destroyed or modified, new materials are added. Thus, in using particular characteristics of the archaeological record as evidence of specific behavioral or organizational phenomena, one must see to it that variability contributed by formation processes is understood and taken into account (Schiffer 1978b; Sullivan 1978). Secondly, these studies emphasize that in order to take formation processes into account (using "systemic transformations" [Reid et al. 1975; Schiffer 1976]), one must identify the formation processes (using "identification transformations" [Reid et al. 1975; Schiffer 1976]). To "identify" a formation process is to infer that it occurred. Third, the analytical level at which this identification is achieved is the "deposit" (see Gifford [1981]). Thus, as a prerequisite for making virtually all archaeological inferences, the archaeologist must identify the processes that gave rise to the specific deposits that are to supply relevant evidence. These points have become widely recognized over the past few years, and now much emphasis is placed, at least theoretically, on the problems of *identifying* formation processes (Brieur 1977; Butzer 1982; Gifford 1981; Gladfelter 1981; Lewarch and O'Brien 1981:299–300; Reid 1982; Schiffer 1976; Schiffer and McGuire 1982: 253–254; Schiffer and Reid 1975; Wilk and Schiffer 1981; Wood and Johnson 1978:370).

Formation processes of deposits are identifiable (can be inferred) in principle because they have predictable physical effects. Experimental, ethnoarchaeological, and theoretical investigations have begun to specify these material traces that can help to pinpoint specific processes. I will exploit these studies as well as recent work in vertebrate taphonomy and geoarchaeology to set forth the basic attributes of artifacts and characteristics of deposits that with varying degrees of sensitivity indicate formation processes. By presenting in one framework keys to the practical identification of formation processes, I hope to encourage a more rigorous, consistent, and self-conscious handling of formation processes in inference than has been practiced in archaeology—old or new.

THE TRACES OF FORMATION PROCESSES

The following presentation, which is by no means an exhaustive treatment of the subject, groups into three sections those properties of deposits that may indicate formation processes. It is assumed at the outset that substantive research interests determine how finely one needs to resolve formation processes. Clearly, most contemporary research problems (e.g., subsistence-settlement reconstruction, the spatial organization of activities and social units, and the building of refined chronologies) demand that formation processes of deposits be identified in some detail. In many cases, it must be acknowledged, we cannot now furnish identifications at the required degree of precision. Thus there is a continuing need for basic research on formation processes in a variety of settings. Nevertheless, judicious use of the multiple lines of evidence enumerated below can contribute to an improved match between research questions and archaeological evidence and to more rigorous justifications of inference.

Simple Properties of Artifacts

Size. Artifact size is one attribute consistently implicated in studies of formation processes (DeBoer 1983). Size effects come about because formation processes can (1) reduce the size of artifacts and (2) sort or winnow artifacts by size.

In a study of the Alyawara in central Australia, James O'Connell (1979) found that activity areas near hut and hearth are kept reasonably clean by the removal of larger debris; the latter is deposited nearby in crescentic zones of secondary refuse. Clearly, the principal domestic activity areas of Alyawara camps are characterized by the prevalence of tiny items. These size-sorting effects of clean-up activities and refuse disposal, described by the McKellar Hypothesis (McKellar 1983; Schiffer 1976:188: foreshadowed by Green [1961b:91]), are now well documented in diverse ethnoarchaeological settings (e.g., Binford 1978a:356; DeBoer and Lathrap 1979:129; Schiffer 1978c:244–245; South 1977:71, 1979:218–219). (The McKellar Hypothesis states that smaller items are more likely to become primary refuse in activity areas.) Archaeological applications have even begun to appear (e.g., Abbott and Lindauer 1981; Bradley and Fulford 1980; Lindauer and Kisselburg 1981). In activity areas not habitually cleaned, such as some lithic quarry-workshops, abandoned structures (e.g., Carrillo 1977), and vacant lots (Wilk and Schiffer 1979), larger items can accumulate as primary refuse. The McKeller Hypothesis, it should be stressed, applies only to regularly maintained activity areas.

Artifact size also affects loss probabilities, with small items more likely to be lost (Fehon and Scholtz 1978; Rathje and Schiffer 1982; South 1977). Loss is usually the process responsible for the deposition of small, still usable items—especially those having high replacement cost—in activity and refuse areas (cf. Ferguson 1977:62; Gifford 1980:98). Recycling also may be implicated by artifact size (Ascher 1968:51). In accord with the Frison Effect (Jelinek 1976:22), which notes that a variety of behaviors can transform lithic tools into different forms, recycled lithic artifacts become progressively reduced.

Deposition of artifacts as de facto refuse or their transport as curated items (sensu Binford [1973]) is in part conditioned by size. Ethnoarchaeological studies of recently abandoned structures in settlements (e.g., Lange and Rydberg 1972) have shown that easily replaced large items are more often deposited as de facto refuse, whereas smaller, more costly artifacts tend to be curated (see Gould [1980]). Ebert (1979:68) also suggests that among mobile groups, tools likely to be curated may be made smaller in anticipation of their travels (see also Schiffer [1975d:269]).

Many studies have shown that trampling (by people, animals, and machines) reduces artifact size in predictable ways (Kirkby and Kirkby 1976:236–238) and, in loose substrates like sand, sorts artifacts by size (Behrensmeyer and Boaz 1980:80; DeBoer and Lathrap 1979:133; Gifford 1978:82, 1980:101; Schiffer 1977). For example, larger objects are moved upward and displaced laterally, whereas in loose substrates smaller ones are pressed downward (Stockton 1973; Wilk and Schiffer 1979). Several archaeological investigations have exploited sherd size distribution as a trace of trampling (e.g., McPherron 1967).

A variety of other cultural disturbances, ranging from plowing to use of the Marden brush crusher, have known size reduction and/or size-sorting effects (Baker 1978; Lewarch and O'Brien 1981; Schiffer 1977; Wildesen 1982). In particular, plowing, like trampling, causes greater upward and lateral movement of larger artifacts. It is also likely that certain reclamation processes, such as collecting and scavenging, preferentially operate on specific size ranges of artifacts (Schiffer 1977; Wildesen 1982).

A remarkable array of noncultural formation processes also have size effects, as shown in the following examples.

The basic laws of hydrology developed for sedimentary particles apply to artifacts affected by flowing water (Behrensmeyer and Hill 1980; Gifford 1980, 1981; Shackley 1978; Shipman 1981). For example, the size of sedimentary particles that are eroded and deposited varies with the velocity of the water (Butzer 1971, 1982; Gladfelter 1977; Limbrey 1975; Selley 1976). Thus, in moderately rapid flows, only the larger, heavier artifacts may remain. (See discussions below for further treatments of artifacts as sedimentary particles, a perspective that represents the fruitful convergence of geoarchaeology, vertebrate taphonomy, and research on site formation processes.)

Wind is an especially potent sorting force and operates in a manner similar to that of flowing water (Dancey 1981; Limbrey 1975; Pyddoke 1961). Gentle winds can remove or deposit only clay, silt, and sand-sized particles, whereas heavy winds transport larger particles in the size range of tiny artifacts. Smaller artifacts are also apt to be buried first by eolian deposition (Behrensmeyer and Boaz 1980:80).

Several other natural processes have demonstrable size effects. Smaller bones suffer greater carnivore damage (Behrensmeyer and Boaz 1980:80; Pastron 1974:98), experience higher rates of surface weathering (Behrensmeyer and Boaz 1980; Gifford 1978:81), and undergo accelerated chemical change in aqueous environments (Lenihan et al. 1981:149). Worms and other burrowing animals size-sort artifacts in several ways (Wood and Johnson 1978). For example, only small artifacts can be brought to the surface or be trapped in the burrows of small animals (Limbrey 1975:315; see also Wood and Johnson [1978]). Some of the less widespread processes that have size effects include freeze-thaw cycles in colder areas (Pyddoke 1961:52; Wood and Johnson 1978) and the shrinkage and swelling of clay soils (Wood and Johnson 1978:356).

Although artifact size is one of the most salient indicators of formation processes, relevant information is too rarely collected or reported, as Bradley and Fulford (1980:85) point out. For example, sherds too small to be placed into the type-variety systems of Mesoamerica and the Southwest are often discarded. In most regions, the smallest artifact constituents of a matrix, such as microdebitage, are seldom recovered, despite the availability of suitable sampling techniques that have been around for decades (for references see Heizer [1960]). If we are to use artifact size as a trace of various formation processes, then standard recording procedures will have to be modified to handle the smallest—but often high frequency—finds (Wilk and Kosakowsky 1978). Bradley and Fulford (1980:92) suggest that particle size curves from sediment studies could be adapted for use on sherds. Nested screens of varying mesh size might also hasten the recording process (Wilk and Kosakowsky 1978).

Artifact size is most conveniently represented as the mean, median, standard deviation (Lindauer 1982a), or frequency distribution of artifact weight or volume. Comparisons of one or more of these variables for different artifact materials within and between deposits will, I suggest, be instructive.

Properties like artifact size, which may serve as evidence for inferring myriad formation processes, seemingly present problems of equifinality. Clearly, size data alone will seldom suffice to pinpoint the responsible process(es). For example, is a deposit of mostly small sherds the result of (1) primary refuse deposition in a regularly cleaned activity area, (2) trampled items of secondary refuse, or (3) a secondary deposit formed by fluvial action? To distinguish among these (and other) alternatives, one examines additional traces of formation processes, such as those enumerated below. However, even when multiple lines of evidence are brought into the analysis, the exact genesis of complex deposits formed by many processes may, in our present state of knowledge, remain uncertain.

Density (or specific gravity). In conformity with the principles governing the movement of particles by water and air, we may expect (holding constant other variables) artifact density or specific gravity to affect their transport behavior. It has been shown experimentally that density influences the hydraulic behavior of bone (Shipman 1981:30–31), and probably artifacts of other materials. With the exception of bone, I suspect that most intramaterial variation (e.g., stone, glass, ceramics) will not be great enough to appreciably affect wind and water transport. Clearly, experiments on nonbone artifacts are needed in order to assess the value of computing density, separately from size or volume, for intramaterial comparisons.

Density also affects the rate or prevalence of other environmental processes. For example, in the case of faunal remains, experiments and ethnoarchaeological investigations have demonstrated that resistance to decay and weathering is in part a function of the specific gravity of the bone (Binford and Bertram 1977; Brain 1980:117, 1981).

Shape. Holding constant size and density, shape affects the movement of artifacts by wind and water. Shipman (1981:26) furnishes several measures of bone shape that seem applicable to any artifacts. This variable will most likely be useful in studying sites where fluvial processes are already known to have been at work, such as early hominid localities in East Africa, but more detail is desired on their specific effects.

Orientation and Dip. Orientation and dip of artifacts are two additional characteristics potentially relevant to identifying formation processes. Experiments have shown that fluvial (and sometimes eolian) processes can align artifacts relative to their long axes (see Shipman [1981] for various ways to represent orientation). Generally, the discovery of a patterned orientation is ample grounds for inferring the occurrence of a noncultural process, such as flowing water. Although materials in abandoned constructions, such as walls, are markedly oriented (e.g., Shackley 1981:20), most cultural formation processes, we might suppose, randomize artifact orientations (e.g., see Limbrey [1975:299] on plowing). However, experiments are needed to investigate the possible orienting effects of various kinds of trash-dumping behavior.

Dip is sensitive to a number of cultural and natural processes. Behrensmeyer and Boaz (1980:87) suggest, for example, that trampling in loose substrates can create vertical or near-vertical dips of long bones and presumably other artifacts of similar shape and size. Trampling of smaller artifacts with less extreme shapes is likely to produce a more nearly random distribution of dips (cf. Butzer 1982:102; Isaac 1977:61).

The potential of dip to inform on a variety of cultural processes has not been sufficiently exploited. One can readily appreciate, for example, that artifacts laid down one at a time on an occupation surface generally lie flat, whereas those deposited in quantity at once, such as from a basketload of trash, have much more varied dips. Further experiments are needed "because the factors contributing to dip are not well understood" (Shipman 1981:76).

Use-life Factors. Artifact types ordinarily go through predictable life cycles (Schiffer 1972, 1975a; Rathje and Schiffer 1982), from procurement, through manufacture and use, to deposition in archaeological context. Especially during use and subsequent stages, traces are formed that furnish evidence on cultural formation processes. One of the simplest, most frequently observed traces is whether the artifact is fragmentary or whole. Determining if an artifact was usable at the time of cultural deposition helps to indicate the responsible processes. Burials, caches, and floors of structures, for example, may contain complete or restorable items with much of their use-life remaining. This contrasts markedly with deposits of secondary refuse, where scarcely an intact item is found. Indications of use-wear or measures of expended use-life may be essential for some studies. For example, by investigating use-wear on a series of Mimbres burial pots, Bray (1982) showed that the vessels, which exhibited use, were not manufactured exclusively as "mortuary wares." As noted previously, replacement cost is another life-cycle characteristic that influences the operation of many formation processes, such as loss, abandonment, scavenging, collecting, curation, and reuse (e.g., Binford 1976; Ebert 1979; Gifford 1978; B. Hayden 1976; Rathje and Schiffer 1982). Use-life characteristics have long been employed to distinguish among gross types of cultural formation processes and will continue to be important in the more refined studies now required.

Damage. A vast number of cultural and natural formation processes acting on artifacts leave behind recognizable patterns of damage (Goodyear 1971). South (1977:217–218) has called attention to the importance of considering condition when interpreting artifacts, a position underscored here. Although damage patterns on lithic and bone items have been vigorously investigated, there is as yet little to be said about other artifact materials.

Speculation about the natural or cultural origin of particular types of bone fractures, long a pastime of Early Man students in the Old and New Worlds, has recently generated a sizable body of experimental and ethnoarchaeological evidence, primarily on the effects of natural processes (Brain 1981). Binford (1981b:44–49), for example, attributes four types of damage—punctures, pits, scores, and furrows—to the action of carnivore teeth. Several other traces of carnivore bone processing are documented, including spiral fractures and polish (Binford 1981b:49–58), but not all are produced uniquely by carnivores. For example, spiral fractures can be caused by trampling (Binford 1981b:77–80; Myers et al. 1980) as well as by human bone breaking (Bonnichsen 1979). Some effects of bone gnawing by domestic dogs are given by Pastron (1974:98–100), and in a related study Behrensmeyer and Boaz (1980:87) tabulate the skeletal elements likely to be consistently damaged by predators. Other lists of bone damage types and their definitions are supplied by Bonnichsen (1979), Hill (1980:137–143), and Morlan (1980).

More generalized types of bone damage are linked by Shipman (1981:41, 100) to the responsible processes (see also Gifford [1981]). For example, cracking, crumbling, and exfoliation are caused by weathering, whereas eolian transport leads to pitting. Behrensmeyer (1978) has defined and illustrated characteristic stages of weathering. Dendritic etching of bone is a frequently observed phenomenon caused by the action of carbonic acid secreted by roots in contact with the bone (Binford 1981b:49–51; Pyddoke 1961:82). Other chemical changes undergone by buried bone are discussed by Parker and Toots (1980) and Goffer (1980).

The progress made thus far in linking bone damage patterns to specific agents now makes it possible in many cases for the analyst to separate the bones in a given deposit into those subjected to different environmental processes (Shipman 1981:99). The knowledge that the bones in a single deposit have heterogeneous histories (e.g., some weathered, some not) is itself a significant finding (Gifford 1981).

Although stone, particularly the siliceous materials frequently chipped into artifacts, seems impervious to external conditions, it is not (Goffer 1980). Many formation processes leave recognizable, if subtle, traces. For a general treatment on how to distinguish the traces of several different formation processes from use-wear, see Keeley (1980:28–35). Odell (1982:22–23) also discusses recent work on damage other than that caused by use.

Patina is a damage pattern that has long been recognized, but remains poorly understood (Hurst and Kelly 1961). Part of the problem, as Rottländer (1975) shows, is that the term patination describes a set of phenomena produced by various causes (Keeley 1980:29). Some patinas, such as desert varnish, are formed by deposition (see below), whereas others arise through chemical deterioration of the stone (e.g., leaching in acidic or alkaline environments). In still other instances, both deterioration and deposition can occur (Goffer 1980:248–249). Among the factors that affect the nature and rate of formation of chemically induced patinas are composition and surface texture of the stone as well as the pH, temperature, moisture, and chemical composition of the surrounding matrix—if any (see Rottländer [1975] and Goffer [1980]).

Patinas are usually employed as a (weak) line of evidence for relative dating (e.g., Goodwin 1960); recently, hope has been raised, perhaps prematurely, that electron microprobe analysis may facilitate chronometric applications (Clark and Purdy 1979). Up to the present, however, the potential of patinas to yield information on natural processes has been overlooked. Clearly, the diverse causes and effects of patination make it likely that specific patinas can be related to the responsible environmental condition(s). The need for experimental work on other processes of natural weathering is clearly indicated.

Cultural formation processes, too, can sometimes be implicated by patinas. For example, on a single artifact, differences in patination between original and later flake scars—known as "double patination" (Goodwin 1960:301)—point to scavenging or collecting for reuse (J. Hayden 1976;

Villa 1982:282). These same processes are also suggested by variations in the patinas of different artifacts in the same deposit. As available technology is applied to measure minute differences in the degree and kind of patination, more fine-grained analyses of other formation processes may become feasible.

Patterns of damage on lithics (and other artifacts) can also be produced mechanically by windborn particles, especially in deserts. Borden (1971) investigated the wind erosion and polish on a lithic assemblage from a site in the Mohave Desert. His microscopic observations suggest that even short exposures to "sand blasting" leave perceptible traces on some materials, a finding that could be used for determining if (or perhaps even how long) artifacts had been on the surface.

Another familiar process with sometimes dramatic effects is water transport. The battering and abrasion resulting from the contact of water-borne materials are easily recognized. As Keeley (1980:30) notes, "the heavier abrasions usually cover extensive areas of the implement (if not the whole surface), but especially affect the edges and ridges. The striations on these abraded surfaces are numerous and usually randomly oriented." Wymer (1976:329) stresses the development of facets—the smoothing of ridges—on stone tools that were stream rolled, and presents a scale for representing the amount of rolling. Shackley (1974) supplies an abrasion index that is sensitive to lesser degrees of damage, such as that which occurs when a stationary artifact is abraded by moving particles. Olorgesailie furnishes an example of how traces of water transport influence the interpretation of specific deposits (Isaac 1977).

Recycling and secondary use often produce microflakes and chipping that differ from previous use-wear patterns (Frison 1968). Goodyear (1974), for example, has shown how the Dalton bifacial knife is resharpened until it is eventually recycled as an awl or drill. Scavenged or collected lithic artifacts may also be modified in distinctive ways; after all, an abandoned site is a potential quarry-workshop area (Gould et al. 1971:163).

Keeley (1980:31) calls attention to a little-discussed phenomenon, "soil movement effects." He notes that stresses (imposed by various processes) in a deposit can cause artifact movement and contact leading to abrasion and microflaking. "White scratches" (Keeley 1980:32), which are striations visible to the naked eye that have rough topography and are often found on bulbar scars, are thought to be a distinctive trace of soil movement. The whiteness of these scars is the result of patination; similar unpatinated scratches are also found (Keeley 1980:34).

Trampling, as might be expected, leaves abundant traces, some of them perhaps distinctive. Tringham et al. (1974) found that trampling caused microflaking of tool edges but the scars were less patterned than those produced by tool use (see also Clark and Kurashina [1981:312–313]). Keeley (1980:35) notes that certain microflake types characterize trampled artifacts. In addition, he also discovered shallow striations, set back from the edges, on dorsal and ventral surfaces (Keeley 1980:35). These randomly oriented striations, also noted by Knudson (1979) on trampled glass artifacts, can help to differentiate trampled items from those bearing flake scars of just retouch or use.

Glass and ceramics, as types of culturally produced stone, exhibit many of the same traces of formation processes as do lithic artifacts. Glass, for example, patinates, especially in alkaline environments (Goffer 1980:249)—in some cases after less than a century of burial. Microflaking and abrasion are produced on glass sherds by trampling (Knudson 1979); water transport creates light abrasion overall and, in extreme cases, considerable edge rounding. Ceramic sherds are abraded by trampling; striations are visible on hard pastes, whereas only a generalized abrasion and erosion of the surface may be found on softer wares. Similarly, edge rounding, probably caused by trampling and repeated handling, is pronounced on soft-paste sherds. Barker (1977: 177–178) suggests that degree of sherd damage can help to separate out "residual" sherds in a deposit—those manufactured, used, and deposited at an early time but which were redeposited in association with later ceramics. Studies along those lines could appreciably reduce problems of chronological analysis encountered with heterogeneous deposits of secondary refuse (Schiffer 1982). Natural processes operating on the surface of sites, such as weathering, affect sherds as well as lithic artifacts (Pyddoke 1961:44; Sullivan 1980:245).

Although damage patterns on sherds (glass and ceramics) are likely to furnish a relatively robust indicator of formation processes, the possible contributions of use-wear and the formal properties of the artifacts themselves (e.g., vessel thickness, hardness of paste and slip) to the observed traces must also be assessed. In general, much experimentation is needed on breakage (e.g., Lindauer and Kisselburg 1981), use-wear, and other patterns of damage to glass and ceramic items.

Damage resulting from formation processes is to be found on virtually all other artifact materials, but such modifications have seldom been systematically studied. A few additional examples illustrate the potential offered by these often conspicuous traces, especially of natural processes. Exfoliation of adobe walls near the ground, visible in archaeological structures (e.g., Hayden 1957), is caused by expansion of salts deposited in the adobe by capillary action from groundwater (Hayden 1945). Pollen grains exhibit degradation caused by a variety of processes, such as alternate wetting and drying (Bryant and Holloway 1983). Gasser and Adams (1981) describe the effect of rodent gnawing on seeds using archaeological data from Walpi Pueblo. Thus, even in sites with excellent preservation of perishables, one must look for the traces of rodent processing that have biased the assemblage. Fire is a widespread occurrence often associated with certain formation processes, such as abrupt, unintentional abandonments of structures (as well as their planned destruction), burning of refuse heaps, and forest fires. Traces of burning or exposure to fire are material-specific, easily recognized, and can aid in identifying formation processes (South 1979:217). Finally, pH and other factors of the depositional environment can be learned from corrosion of metals (Goffer 1980; Tylecote 1979).

Patterns and degree of damage unquestionably furnish highly salient information about formation processes. To realize this potential fully, experiments on new materials and continued work on bone and stone will be needed. In addition, along the lines of Behrensmeyer's index of weathering for bone, material and process-specific indices of damage will have to be developed. I hasten to add that initially such indices need not be elaborate nor necessarily fine-grained to be effective.

Accretions. Other potentially informative modifications of artifacts are accretions—the accumulation of substances on an artifact's surface. Thus, caliche, desert varnish, lichens, and similar accretions indicate past processes, especially natural processes. For example, various conditions of the depositional environment are thought to promote the growth of caliche on artifacts, whereas others lead, subsequently, to its dissolution (Hayden 1982). In dry caves or rockshelters one sometimes finds matted hair clinging to animal bone, indicating that the latter had travelled at least part way through the alimentary canal of a carnivore (Brieur 1977:60; Brain 1981). Some accretions, such as ash or sediments, may supply information on a variety of cultural formation processes—especially those that took place in settings before artifacts reached their recovery locations. For example, in secondary refuse in pueblo rooms one sometimes finds in the same depositional unit sherds with and without ash coatings. One may surmise that the ash accumulated on the sherds in a previous depositional setting, such as in a heap of trash and ash swept up from a room floor. Clearly, the systematic examination of accretions, especially those representing traces of cultural formation processes, has scarcely begun.

Observation and recording of many traces mentioned in this section may be carried out on a sample of artifacts. Obviously, if a recovery unit contains 6,000 sherds that are to be placed into a number of size, abrasion, and edge-rounding categories, a sample of several hundred—at most—will suffice (Seymour 1980).

Complex Properties of Artifacts

Many traces of formation processes can be derived from abstract properties of artifacts as they relate to each other in space. I now turn to some of these more complex properties.

Artifact Quantity. A multitude of formation processes have effects on the total quantity of artifacts in a deposit and on the frequencies of constituent types. To take the simplest example, decay processes diminish—sometimes to zero—the number of "perishable" artifacts. Processes of cultural deposition vary in their rates and duration, and thus produce different artifact totals. For example, the de facto refuse assemblages of a settlement have few items compared to the amount of refuse deposited over several decades in that settlement's dumps. Although the archaeological literature overflows with quantitative analyses, the capability of simple variables such as total quantity, ratios, and frequency distributions to supply insights into formation processes has been insufficiently explored. Because it is a trace of so many formation processes, artifact quantity will be involved to varying degrees in the examination of most other traces. However, because they are also affected by a host of systemic behaviors, quantities must be interpreted with great care.

Vertical Distribution. Stratigraphers have long made use of vertical patterns to discern various formation processes. As a result, a great deal of relevant information is already well known and need not be repeated here (e.g., Harris 1975, 1977, 1979). Several points, however, deserve emphasis. Whereas the intent of stratigraphic studies is primarily to establish a chronological sequence of depositional units, the present perspective emphasizes the need to identify the processes responsible for each depositional unit. In addition, stratigraphic interpretation traditionally has been insufficiently concerned with vertical effects *within* depositional units (cf. Bunn et al. 1980:116) or with formation processes that can confound the usual visual criteria for distinguishing discrete strata (e.g., Butzer 1982:107–112; Foley 1981:168–172; Gifford 1978; Limbrey 1975; Villa 1982; Wood and Johnson 1978). In short, refinements of stratigraphic interpretation, including microstratigraphy, are clearly needed (Schiffer 1976:137). For empirical studies of vertical artifact movement in stratified sites, see Matthews (1965), Rowlett and Robbins (1982), and Siiräinen (1977).

Horizontal Distribution. The horizontal distribution of artifacts within deposits (and sites) is a line of evidence on formation processes that has been exploited only rarely. Unquestionably, many formation processes (especially cultural) have appreciable spatial effects. Major differences in patterns of cultural deposition can sometimes be discerned using distributional data. For example, South (1977:47–80) used information on artifact distribution patterns relative to structures on historic sites to distinguish several varieties of refuse. In another study, Goodyear et al. (1979:80) used the "intrasite distribution of temporally diagnostic artifacts" on a shallow Archaic site to identify separate episodes of occupation (for related studies, see Hanson and Schiffer 1975; House and Wogaman 1979; Reid et al. 1975). Other discussions of spatial analysis, especially of surface remains, are supplied by Lewarch and O'Brien (1981).

Many seemingly sophisticated spatial studies in archaeology are badly flawed because, in the analysis, evidence on activity distributions and on formation processes has been conflated. Remarkably, even recent compilations of intrasite techniques of spatial analysis fail to consider the contributions of formation processes to artifact distributions (e.g., Orton 1980:142–155). Much attention has been devoted to recognizing spatial clusters of artifacts on "occupation floors," on the assumption that such clusters denote activity areas. But clustering is also produced by refuse disposal patterns (see Andresen et al. [1981:24]), with degree of concentration of refuse varying directly with the intensity of settlement occupation (Murray 1980; Rathje and Schiffer 1982:116; Schiffer 1972). Degree of artifact clustering can also be affected by various disturbance processes, both cultural and noncultural (Wilk and Schiffer 1979; Sivertsen 1980). Statistically co-varying sets of artifacts that usually have spatial configurations also can be produced by cultural formation processes (Carr 1984; Schiffer 1974, 1976).

Artifact Diversity. Artifact diversity is a characteristic of deposits particularly sensitive to cultural formation processes. It is easily measured with a host of available techniques that can be applied to material types or to techno-functional types. Coefficients of variation, measures of entropy, and, especially, simple ranges can serve to compare artifact diversity among deposits. In the remainder of this discussion, I use "diversity" to mean range of types.

In accord with the Clarke Effect (Schiffer 1975d; Rathje and Schiffer 1982:119), artifact diversity is responsive to variations in the occupation span of settlements (see also Yellen [1977a] and Schiffer [1978c:244]). Because differences in the functions of settlements and activity areas also influence artifact diversity, one must employ this measure with care. Nevertheless, artifact diversity is a strong line of evidence that can be used in many cases to differentiate various refuse sources. For example, highly specialized activities, such as ceramic or lithic manufacture, contribute a low-diversity stream of refuse. Thus primary refuse or discrete deposits of secondary refuse from such activities exhibit very low diversity. On the other hand, great diversity is found in secondary refuse deposits containing refuse streams from a settlement's entire range of activities (Boone 1982; Schiffer 1976). Moreover, among deposits in sites occupied for at least several years, secondary refuse deposits should generally exhibit the greatest artifact diversity.

Artifact Density of Deposits. The overall artifact density in a deposit is a direct trace of the concentrating and dispersing effects of various formation processes (Green 1961a:51). For example, similar secondary refuse deposits that differ only in artifact density may have formed at different rates, consisting of different ratios of cultural materials to noncultural sediments (Heizer 1960). In some cases, comparisons based on densities for each type of material (e.g., sherds, lithics, animal bone, shell) might be useful. The term "concentration index" is usually applied to artifact densities specific to certain types or materials (Heizer 1960:100; Willey and McGimsey 1954). As more experiments are carried out, new applications of the concentration index and overall artifact density are likely to be devised.

Measures of Disorganization. Cultural formation processes often produce deposits containing associated artifacts that were not intimately related in systemic context. Alyawara secondary refuse areas, for example, include the remains of myriad activities ranging from meal preparation to car repair (O'Connell 1979). To see this process in action one need look no farther than one's own household refuse. Not only do many processes bring together unrelated items, but they can also separate items used together as well as parts of the same artifact, leading to their occurrence in different deposits. This phenomenon is known as the "principle of dissociation" (Rathje and Schiffer 1982:107). Of the many characteristics that may monitor these disorganizing effects, I mention a few that seem to have much promise.

The Completeness Index (CI) should be very sensitive to variations in formation processes. In illustrating how it is calculated, I will use ceramic artifacts; implications are drawn below for other artifact materials. The appropriate unit of analysis is the once-whole individual artifact (e.g., a pot or bottle), as determined from the remnants that survive in a deposit. For each deposit, sherds are sorted into the vessels from which they came. (The number of such vessels, of course, is analogous to the MNI in faunal analysis and is itself a useful characteristic.) After groups have been formed consisting of sherds from the same original vessel, one computes the CI by determining the fraction of *each pot* represented by the sherds. This is accomplished by dividing the total weight of sherds by the weight of a similar whole vessel. To summarize the composite CIs for all vessels in a deposit the investigator can employ various averages—the range, frequency distributions, and, especially, the cumulative frequency graph. High mean values of the CI, approaching the maximum of 1.0, should be found in some types of de facto refuse, grave goods, caches, and certain kinds of secondary refuse (e.g., sanitary landfills). Low mean values of the CI (near 0.0) are to be expected, for example, in primary refuse from regularly cleaned activity areas and in various deposits that have been extensively reworked.

It should be evident that deposits with a high mean CI could exhibit a range from large numbers of small fragments to small numbers of large fragments (Hulthén 1974). This potentially interesting variation is monitored by the Fragmentation Index (FI). To compute the FI, the researcher returns to the piles of fragments, each of which represents a once-complete object. For each of the latter, the investigator counts the number of pieces (P) and inserts it into the following equation:

$$FI = \frac{1}{1 + \log_{10}(P)}$$

The fragmentation index ranges in value from 1.0—an artifact represented by one piece—to numbers approaching 0.0, which indicate intense fragmentation. Formal properties of the ceramics, such as vessel size, will to some degree influence the FI. Experiments are needed to determine the conditions under which appropriate corrections should be introduced.

It should be recalled that the appropriate analytic unit for calculating these indices is the deposit, variously defined (e.g., contents of a room floor, a layer in a trash mound, a segment of construction fill). Obviously, in many cases one is dealing not with an entire deposit, but a sample. Herein lies the advantage of the CI and FI: results should be relatively insensitive to all but the most severe sampling problems—presuming that the sample size (i.e., number of fragments) from each unit is sufficiently large. Although experiments are required to determine the minimum acceptable sample sizes under various conditions, I anticipate that they will be mercifully small.

Ceramic and glass artifacts are well suited to calculation of the CI and FI. More importantly, the indices for these types of artifacts will be monitoring primarily formation processes, as opposed to the systemic processes that complicate their applications to lithics and animal bone. By examining attributes of ceramics and glass, such as sherd thickness and curvature, color of slip and paste, and nature of the temper (Sullivan 1980:265), the sherds from individual vessels can be segregated—assuming that individual vessels have some unique attributes. When the latter condition is not met, as in mass-produced pottery, computation of the indices is more problematic. One possibility is to divide the number of sherds by the minimum number of vessels; the latter may be calculated on the basis of specific diagnostic parts, such as rims, necks, or bases (Millett 1979). Under the more favorable conditions encountered in many prehistoric settings, it may be possible—given a sufficiently large artifact sample—to base the indices entirely on rim sherds (cf. Orton 1982:10–11). For other potentially useful discussions of pottery quantification, consult Orton (1975) and Vince (1977).

For a variety of reasons, the CI and FI are not adapted for use on chipped stone and animal bone. When it is possible to determine without reassembly (see below) which flakes came from the same core or which bones came from the same animal, the indices might furnish useful information, subject to the same limitations as those of reassembly. For example, it is obvious that deliberate animal burials and intrusive rodents that died in their burrows will exhibit high values of the CI (Olsen and Olsen 1974; Thomas 1971).

If the investigator is willing to aggregate specimens by species (or higher taxon), then the "corrected specimens per individual" (CSI) may provide information on faunal completeness. Thomas (1971:367) supplied the formula for the CSI, but to reduce ambiguities I have modified the symbols:

$$\mathrm{CSI} = \frac{100(\mathrm{NISP})}{(\mathrm{E})\,(\mathrm{MNI})}$$

in which NISP is the number of identified elements for that species (Grayson 1979:201) and E is a species-specific constant approximating the number of recognizable elements (Thomas 1971: 367–368). The CSI varies from less than 1.0 (highly incomplete animals) to about 100 (whole animals) and permits one to compare different species. A quick-and-dirty approximation to the CSI, not valid for the interspecific comparisons, is simply NISP/MNI, which (based on data in Thomas [1971:368]) varies from 1.0 to numbers ranging from about 15 (small species) to about 125 (larger species). Fortunately, intraspecific comparisons are more apt to indicate differences in formation processes than simply variability in procurement, butchering, and distribution patterns. In any event, one must recognize that completeness indices for faunal remains will be affected by many systemic factors in addition to formation processes.

Recent work in zooarchaeology has shown that the CSI and other measures are appreciably influenced by sample size (e.g., Grayson 1981). While these sampling effects are important and need to be assessed, in many cases it is formation processes (and not recovery processes) that determine sample size. For example, in a completely excavated room in a Southwestern pueblo, the archaeologist may have recovered complete populations of various deposits, such as floor de facto refuse and secondary refuse in the fill. The number of artifacts available from each deposit is a function not of sample size per se but of depositional processes. Sample-size effects in such situations are much more problematic. Clearly, application of measures of disorganization, particularly of faunal remains, must be carried out in full awareness of possible sample size effects.

Artifact Reassembly. Traditionally, reassembly of artifacts—mostly pottery—primarily functioned to furnish museums with displayable specimens. In recent decades, however, investigators have sought to secure information from the spatial patterns exhibited by the fragments of once-whole objects. I now examine the technique of reassembly, which goes under the names "cross-mending" and "refitting," in order to evaluate its potential to help identify formation processes.

A number of archaeologists have reassembled ceramic and glass artifacts in order to establish contemporaneity between otherwise separate deposits (e.g., Burgh 1959). As South (1977:291) notes,

> Cross mending of artifacts is an important means of associating features at one moment in time, such as the recovery of a white Salt-glazed stoneware teapot from a number of features. The gluing of these fragments together joins the features as well . . . The same applies to cross mending of fragments from various stratigraphic layers which bonds the stratigraphy into a single temporal unit.

Underlying this use of reassembly is the assumption that fragments of an individual artifact were deposited in different places at about the same time. This assumption is not always warranted (Lindauer 1982b). For example, several deposits containing some of a vessel's sherds may be subsequently mixed with later or earlier materials and redeposited, while sherds in other deposits remain undisturbed. For Hohokam mounds and Maya temple fill, such a scenario is far from unlikely. Although ceramic reassembly is helpful in determining contemporaneity of depositional events under some conditions, it has a great, but as yet unexplored, potential for serving as evidence on the mode of formation of deposits (Lindauer 1982b).

Lithic reassembly has become popular in recent years, sometimes yielding impressive results. However, because lithic cores were never whole artifacts in the same sense as a pot or glass bottle, core refitting, with some exceptions, is not a technique that sensitively and uniquely indicates formation processes. Indeed, a variety of processes, including manufacture and use, contribute to the dissemination of the products and by-products of each core. The resulting artifact distributions do not, therefore, unambiguously monitor formation processes or activity patterns. One way around this problem is to focus only on those lithic artifacts, such as bifaces, that when whole did function as an entity in systemic context. Roper (1976), for example, constructed a crude measure of plowing displacement on the basis of cross-mends in bifaces. Goodyear (1974) used biface cross-mends to investigate temporal relations among "living floors" at the Brand site. Biface fragments, however, can be reused or scavenged, factors that need to be considered in future studies.

An elegant application of lithic refitting to investigate formation processes was carried out by Villa (1982) on materials from Terra Amata (see Bunn et al. [1980] for another exemplary study). By refitting lithics from this apparently simple site, she discovered evidence for an appreciable amount of postdepositional movement of artifacts. Although the exact processes that mixed the artifacts into different geological layers are not pinpointed (Villa 1982:282), Villa's demonstration of a kind of disturbance hitherto ignored has many implications for the analysis of presumably discrete archaeological layers. For additional references to lithic refitting studies see Cahen et al. (1979:663).

Fragments of individual bones can, like lithics, be reassembled. Bunn et al. (1980) performed such an analysis for an early hominid site in Kenya, furnishing information on activity patterns and on formation processes. Although it may be possible under favorable circumstances to perform some reassembly of elements into animal skeletons (see Villa 1982:285), ordinarily this cannot be achieved reliably (Grayson 1979:202). Moreover, like lithics, the dispersal of animal parts may result from preparation and use, not just formation processes.

Degree of completeness and articulation of human skeletons, along with other evidence on manner of burial, are attributes useful in distinguishing primary and secondary interments and in indicating, generally, the degree of "post-mortem handling" (Brown 1981:31). Chapman and Randsborg (1981) properly stress the need to study more intensively the formation processes of human burials.

Artifact reassembly is a technique with much promise. In order for it to be realized, the investigator must always keep in mind, especially for lithic and bone artifacts, that past activities *and* formation processes can both contribute to the observed patterns.

Representation of Parts. In lieu of skeletal reassembly, taphonomists and faunal analysts have investigated overall patterns of representation of elements and major portions of elements (Binford 1978b; Gifford 1981; Shipman 1981). It has been learned from ethnoarchaeological and experimental studies that many processes, ranging from curation behavior to weathering and bone collecting by porcupines, operate selectively (e.g., Behrensmeyer and Boaz 1980; Binford 1981b: 42–44, 210–242; Gifford 1981; Pastron 1974; Shipman 1981; Yellen 1977b). Clearly, computation of the representation patterns of elements and element fragments is an efficient and relatively sensitive approach to recognizing the formation processes of faunal remains.

Analogous techniques can be devised for discerning patterns of part representation of other artifact classes. For example, sherd representation figures may indicate whether potters preferentially selected body, base, or rim sherds for recycling into temper. As another example, a high ratio of biface bases to tips in the remains of a base camp suggests that, after breakage, the bases were curated, probably tagging along with the haft (Goodyear 1974; Binford 1976). Creative experiments will disclose other potentially fruitful ways to use patterns in artifact part representation to indicate formation processes.

Other Properties of Deposits

A final set of characteristics sensitive to formation processes includes sediments, ecofacts, chemical properties, the structure and context of deposits, and site morphology.

Sediments. To the field archaeologist the most obvious, and frequently the most abundant, constituent of a deposit is dirt (Renfrew 1976:4). Dirt, properly called sediment, is the subject matter of sedimentology. Butzer (1982:78) has emphasized that "people and animals are geomorphic agents that produce a specific range of archaeological sediments that require special attention and interpretation." Traditionally, in the interpretation of archaeological sediments, natural processes have received major emphasis (e.g., Butzer 1971; Gladfelter 1977; Hassan 1978; Limbrey 1975; Pyddoke 1961). As Whittlesey and others (Butzer 1982; Stein 1982; Whittlesey et al. 1982; Wildesen 1973) point out, however, in many situations the sediment is culturally deposited or modified and is thus an artifact. As this perspective is elaborated by geoarchaeologists, the traces of a variety of cultural formation processes will certainly become evident. In the meantime, I shall briefly treat the extant framework for handling sediments and occasionally indicate possible lines of inquiry. For general discussions of sediment sampling and analytic procedures, see Butzer (1971, 1982), Catt and Weir (1976), Limbrey (1975), Selley (1976), and Shackley (1975).

A frequent question posed by lay people to the field archaeologist is: Where did all the dirt come from? All too often, a precise answer to this question is unavailable. This question, however, is a good one, and it is incumbent upon the archaeologist to ask it, and seek answers, for specific deposits. Butzer (1982:80) lists in addition to water and wind several agencies that introduce mineral sediments into archaeological sites: human feet, hide and fur of game animals, feces, mud wasps, and nesting birds. To these can be added burrowing animals, particles adhering to clothing, and roof falls in caves and rockshelters. Some of these agents, it should be noted, can also remove or erode sediments. In many deposits, the immediate sources of sediments are nearby alluvium brought in for construction (Davidson 1976) and previously deposited materials from other portions of the site—including "floor sweepings" (Green 1961a). I now turn to the properties of sediments that are studied archaeologically and that can furnish information on formation processes.

The most commonly recorded attribute of archaeological sediment is color (see Limbrey [1975: 256–259]). The color of a sediment is complexly determined by a number of factors relating to formation processes, including parent materials, humus and moisture content, soil chemistry, time span of formation, and cultural constituents. Thus, differences in sediment color indicate differences in formation processes (although the converse is not necessarily true). In cultural deposits, it is not just color, but color variations within a single deposit that take on significance (Limbrey 1975:259). For example,

> at Town Creek Indian Mound in North Carolina there is an orange clay subsoil underlying the red clay subsoil . . . pits such as burials that were dug into the orange layer and backfilled almost immediately contain flecks of orange clay in the fill. . . . Pits allowed to fill with midden are easily distinguished by the absence of the orange clay flecks [South 1977:285].

Swirl patterns implicate soft-sediment deformation, for which a variety of cultural and natural processes may be responsible. A closely related property, sensitive to formation processes, is the nature of the boundary between sediments of different colors (Limbrey 1975:269–270). For example, sharply defined pit boundaries indicate an absence of worm activity. A general discussion of boundaries and interfaces between strata is provided by Harris (1979:38–48).

Texture, another frequently recorded property of sediment, refers to the frequency distribution of particle size. The ability of texture to reflect formation processes, particularly of the natural environment, is well known (see the many archaeological applications in Davidson and Shackley [1976]); usually, however, other lines of evidence are needed for isolating the precise process. Shackley (1975, 1981) and Limbrey (1975) present basic principles as well as appropriate analytic techniques.

The surface morphology of sediment particles, seen through the microscope (optical and SEM), may help to indicate the genesis of a sediment (Shackley 1981:16). In particular, Dincauze (1976:11) suggests that chipping or stone boiling debris contributes tiny angular mineral particles to sediments; this hypothesis has now been confirmed experimentally (Fladmark 1982). Further studies of grain morphology in cultural sediments are clearly indicated. The morphology of larger particles, especially those found in rockshelters, provides traces of numerous noncultural processes (e.g., Laville 1976).

Formation processes can also be illuminated by various inhomogeneities in a sediment, sometimes referred to as fabric (Butzer 1982; Shackley 1981). For example, organic materials in a deposit may decay, creating voids, "which are then filled with new sediment or stabilized by the precipitation of solubles" (Butzer 1982:89–90). The filled voids of rootlets might indicate in a deeply buried horizon that the surface had once stabilized long enough to allow plant growth (cf. Limbrey 1975:265).

A final property of sediment is the resistance of a substrate to an applied force, such as a foot pressing downward; this property has been labeled "permeability" in trampling studies (e.g., Gifford 1978:83; Schiffer 1977:23; Wilk and Schiffer 1979:533). Because permeability already has a precise meaning in sedimentology, a less ambiguous term should be employed, perhaps penetrability or degree of compaction. As noted above, loose substrates trap primary refuse as well as trampled and lost items. Cultural activities also create deposits varying greatly in their degrees of compaction (Pyddoke 1961:12). For example, people and animals (Watson 1979:157) walking can produce more compact surfaces; other activities, such as filling a pit with sand or humus-rich sediment, can reduce compaction. In measuring this variable, one must allow for the possibility that various postdepositional processes have altered the degree of compaction. For example, compaction is increased by the decay of organic matter and intrusion of mineral binders, such as calcium carbonate, into a deposit. Similarly, one cannot conclude, as did Hughes and Lampert (1977), that lithification of a deposit was so rapid that various disturbance processes could not have acted after cultural deposition.

Many advances in sedimentology are to be expected in the years ahead, particularly as the traces of various cultural formation processes are sought, perhaps initially in experimental archaeology and ethnoarchaeology. The ubiquitous dirt we labor so hard to remove is itself an artifact that has much information to disclose.

Ecofacts and Other Intrusive Materials. In addition to a mineral fraction, archaeological sediments contain a host of other materials that serve as traces of the environment(s) in which they formed (Pyddoke 1961:76–78; Shackley 1981). Insects (Shackley 1981), vertebrate remains (e.g., bones, hair, feathers), feces, plant parts and seeds, pollen (Bryant and Holloway 1983), plant opal phytoliths (Rovner 1983), land snail shells (Evans 1972), various concretions, nesting materials (of birds, rodents, and insects), and humus are among the widely studied ecofacts found in many cultural deposits that may furnish evidence on natural formation processes.

A long-standing question in many areas is the relative contribution of cultural and noncultural processes in the deposition of ecofacts, especially animal bone (Binford 1981b). Relying on previously mentioned properties of bone assemblages, several investigators have showed that cave sites in particular contain much bone laid down by carnivores and scavenging animals (Brain 1981; Brieur 1977).

As several examples make clear, ecofacts may also help to identify cultural formation processes. In many environments weedy plants colonize thin scatters of refuse, leaving behind characteristic pollen. If that deposit is later buried or scooped up and used as construction fill, the pollen from weedy plants should disclose that it was for a time a surficial deposit (cf. Shackley 1981:85). Many insects, such as beetles, prefer habitats that include decaying vegetation. If such species are found, for example, in a deposit of secondary refuse that lacks preserved macrofloral remains, one can propose that such materials were present but decayed (cf. Shackley 1981: 142–144). Exploiting the potential of ecofacts to yield information on cultural formation processes depends on the recognition that many environmental materials are culturally deposited or are deposited in microenvironments created by cultural formation processes (Greig 1981).

Geochemistry. Sporadic efforts over many decades have brought us to the threshold of a recognizable "geochemical archaeology." Although there has been progress, particularly in the area of prospection techniques (Carr 1982), more experimental work remains to be accomplished (e.g., Wildesen 1973).

A variety of chemical properties of deposits, such as pH, moisture content, and temperature, have been shown to condition or reflect the operation of both cultural and noncultural formation processes. These are sufficiently well known to require no elaboration (for examples, see Rathje and Schiffer [1982]). Additional information on formation processes, particularly cultural deposition, is found in the presence of particular elements and ions, many of which are the only remaining traces of some original constituents of the matrix (Cook and Heizer 1965; Butzer 1982; Carr 1982). For example, on the basis of large amounts of mercury (Hg) in the soil of the Neville site, Dincauze (1976) was able to argue that the locality had been used during Archaic times to process anadromous fish. Butzer (1982:82) suggests that "gas chromatograph analysis of amino acids may identify animal residues from bone, fat, blood, etc." He goes on to propose that the sophisticated technology of organic chemistry may permit the identification of other deposited materials that have decayed (Butzer 1982:82; see also Mackenzie et al. [1982]). Chemical tests can, on occasion, differentiate cultural from noncultural features (e.g., van der Merwe and Stein 1972). The ash content of a deposit may help to pinpoint the sources of refuse.

Geochemical archaeology has an important role to play in understanding formation processes and in interpreting surviving evidence. In particular, the chemical makeup of archaeological sediments can assist in resolving some problems of "negative evidence" (cf. Stone 1981), because geochemical studies may indicate (1) if conditions were favorable for the preservation of specific materials in a given deposit and (2) whether specific materials were in fact once present in a deposit. Clearly, if the chemistry of the deposits has not greatly changed, geochemical investigations can aid us in learning when the absence of evidence is really evidence for absence.

Structure and Context of the Deposit. A final set of characteristics, relating to the structure and context of a deposit, affects the probability that a given deposit has been subjected to particular cultural and noncultural formation processes. For example, refuse deposited in structures and sealed by later floors has less chance of being scavenged and disturbed than refuse in extramural areas (Rowlett and Robbins 1982:76). Abandoned pits used originally for storage or quarrying will attract refuse and human wastes (Green 1961b:92; Hayden and Cannon 1982; Lindauer 1982a; Watson 1979:119; Wilk and Schiffer 1979). Accessibility to modern roads affects the probability that sites will be surface-collected by casual visitors (Lightfoot and Francis 1978).

Noncultural formation processes, too, vary in different settings. Bones deposited in roofed pueblo rooms are generally not weathered, whereas those in extramural areas deteriorate (unless they were rapidly covered by later deposits). Among the Dassanetch in east Africa, Gifford (1978, 1980) showed that the bone remains of a butchery camp were preserved by gently deposited flood sediments, whereas bone left for long periods in surface context would slowly disintegrate. Clearly, the structure and context of a deposit influence the occurrence probabilities for various cultural and natural formation processes.

Site Morphology. A host of other traces are subsumed by the term "site morphology." Factors such as mound slope (Davidson 1976; Kirkby and Kirkby 1976), furrows and plow scars, and potholes furnish strong evidence on the occurrence of many cultural and natural formation processes. Such processes may affect the entire site (which can be viewed for some purposes as a single deposit) or specific deposits within it. Most such macrotraces are well known and require no further treatment.

DISCUSSION

Having duly noted in the previous sections that the traces of formation processes are diverse and ubiquitous, the reader may pose the logical question: Just how many properties must one record and study in order to identify the formation processes of a specific deposit? Obviously, the more relevant evidence one uses, the greater the precision and accuracy of the resultant identifications. Thus, if a research problem and its inferential needs require one to learn how each deposit was formed in minute detail, then it will probably be necessary to examine a great many characteristics. In other cases, however, one's research problems and their attendant inferences require a less definitive specification of formation processes. In this section I review several practical approaches for exploiting the plethora of evidence on formation processes.

Use of Extant Knowledge

As Reid (1982) has pointed out, a large number of specific formation processes and a much larger number of potential combinations of processes could have contributed to the genesis of any deposit. Fortunately, the investigator can reduce the almost infinite set of possibilities to a more manageable number by applying extant knowledge. The latter comes in several forms (Reid 1982), of which the most important for present purposes are: (1) general principles (c-transforms and n-transforms [Schiffer 1976]) that describe the actions of formation processes and that specify conditions known to favor or curtail the operation of particular processes, and (2) empirical generalizations that specify the prevalence of certain processes specific to localities, societies, or sites.

Environmental parameters, such as landform and temperature/precipitation patterns, determine the occurrence of many formation processes. For example, in areas that have been warm deserts during periods of human occupation, cryoturbation, frost heaving, and other cold-environment processes can be ruled out immediately, whereas eolian deposition or deflation and rodent burrowing most likely took place. Similarly, mobile populations make use of highly curated technologies (Binford 1973, 1976, 1979) and probably engage in a considerable amount of recycling (A. Goodyear 1979). Knowing this, the investigator of Paleoindian sites, for example, would test for the effects of recycling and curation behavior. In sedentary settlements, especially those occupied in excess of several decades, abandoned structures are often used as receptacles for secondary refuse (see Butzer [1982:90–92]). Thus, when excavating and analyzing structures in such settlements, one must take care to distinguish the processes responsible for depositing floor-contact materials (Schiffer 1976), only some of which may have been laid down as primary or de facto refuse. As more is learned about the general noncultural and cultural factors that condition the occurrence of specific formation processes, archaeologists will be able expeditiously to rule out some processes and assign high probabilities to others in given research contexts.

"Local expertise," gained from familiarity with previous archaeological investigations in a locality or region, also figures prominently in making the study of formation processes routine. It is useful to regard local expertise as a set of empirical generalizations that, unlike laws and theories, have definite *time-space* boundary conditions (Reid 1982; Reid et al. 1975). For example, although Hohokam secondary cremations show abnormally low bone weights, bones from more than one person are sometimes found in the same cremation deposit (Birkby 1976). Apparently, the Hohokam were not meticulous when it came to gathering up the remains of a cremated individual for burial elsewhere, leading to "multiple cremations" and to low bone weights (Reinhard and Fink 1982). One possible outcome of this cultural practice is that portions of seemingly independent deposits may have derived from the same cremation event. South's investigations of American colonial sites have shown that secondary refuse tends to accumulate in predictable ways: "adjacent" secondary refuse near entrances to structures and "peripheral" secondary refuse in more distant places (South 1977). In the British sites of the eighteenth century, most refuse was apparently of the "adjacent" variety (South 1977:48). Given this knowledge, the archaeologist is in an excellent position to search British sites for and begin the process of interpreting such deposits. In the eastern United States, a substantial fraction of prehistoric sites, even shallow and small ones, are multicomponent (Schiffer and House 1975; House and Wogamon 1979). The investigator who knows that any site has an appreciable probability of containing evidence of many occupations will seek ways to deal rigorously with the resultant complexity (e.g., Goodyear et al. 1979). The reader could doubtless supply additional examples of useful empirical generalizations from other regions.

Although formation processes are highly varied and their potential combinations seemingly infinite, regularities—both general and of more restricted nature—help us to sort out the more (and less) likely probabilities for the cases at hand.

Analytical Strategies

Hypothesis-testing: A Hypothetical Example. In well-studied sites and localities, identification of formation processes can follow a hypothesis-testing format. Examination of a number of salient characteristics of deposits furnishes a basis for a series of alternative hypotheses regarding specific formation processes. For example, McGimsey (1980:39) describes several floor assemblages found in a large pueblo in west-central New Mexico:

> Some of the rooms, with a large number of artifacts and whole vessels littering the floor, apparently stood intact until natural decay and weather brought about their collapse. (In this connection it is interesting to note that very few sherds found on floors could not be assigned to restorable vessels.) [parenthesis in original]

The principal hypothesis to account for the whole vessels, given their high degree of completeness and their floor provenience, is that they represent de facto refuse. Another, less probable hypothesis is that the whole vessels were placed in an abandoned room to accompany a body (as occurred at Pueblo Bonito). As bodies are not reported from the room floors, this hypothesis is excluded. Because no information even suggests another possibility, the de facto refuse hypothesis is retained. If one were going to identify households and compare de facto refuse assemblages among them, it would be necessary to assess the effects of curation behavior and scavenging on the artifact inventories.

If a research problem required use of the remaining sherds that, judging by McGimsey's statement, would represent vessels having very low completeness indices, then their mode of deposition would have to be ascertained. Drawing on local expertise, one can frame several hypotheses. First of all, these sherds may be primary refuse, the few remnants of vessels once used and broken in the rooms, the majority of sherds from which were discarded elsewhere as secondary refuse. If primary refuse, of course, then these sherds can supply evidence on the use of the room.

Another possibility is that the sherds were originally deposited on the roof, which collapsed or deteriorated, bringing them into floor contact. A third hypothesis is that they were tossed into the room after its abandonment, as secondary refuse. Many lines of evidence are available for evaluating these hypotheses, including the nature of the sediments resting on the floor as well as the spatial distribution, size, and amount of edge-rounding and abrasion of the floor sherds. Since these data are not supplied in the report, none of the hypotheses can be excluded. When the investigator controls the recovery stage of a project, hypothesis-testing, which can and should begin in the field, may efficiently achieve reliable conclusions about formation processes.

A Multivariate Approach. In some instances the investigator may have little prior knowledge about formation processes; thus, a great many potentially independent traces will have to be examined in order to identify the formation processes of the deposits in question. A logical adjunct to the use of multiple indicators, especially where little is known about the processes that might be involved, is to analyze a set of deposit data with multivariate statistical techniques. Specific models of formation processes can then be built to account for the covarying characteristics and for the similarities and differences among the deposits.

This approach has been taken at Cuello, a Maya site in Belize (Seymour 1980; Wilk and Kosakowsky 1978). Investigators carried out intensive recovery of large and small artifacts within representative samples from different deposits. A variety of traces of formation processes were recorded for each deposit and the resultant data were cluster-analyzed. Deposits were thus grouped in terms of their major formation processes. Interpretations that accounted for the similar characteristics of deposits were then offered for each group. The analysis stage of the Cuello Project is still underway, but the preliminary results have been promising. Indeed, they suggest that many of the mound-fill deposits in Maya sites, which customarily are not analyzed because they are thought to be devoid of temporal or behavioral information, have considerable potential to contribute to both kinds of inference.

The use of multivariate techniques on the traces of formation processes has other potential applications that need to be explored.

Use of Published Data. Many extant reports furnish scant evidence for studying formation processes. Even so, the attempt must be made to identify formation processes when using data from old reports, as a somewhat lengthy example shows.

Lightfoot and Feinman (1982) recently sought to study the development of suprahousehold organization among Mogollon pithouse villages. Specifically, they tried to demonstrate the presence of village leaders or "big men" having political authority. They examined house size, storage capacity, agricultural produce, and exotic goods, analyzing the published data on nine sites from east-central Arizona and west-central New Mexico. I focus specifically on their claim to have shown, on the basis of the distribution among pithouses of exotic items such as turquoise, marine shell, and Hohokam pottery, that the occupants of larger pithouses engaged in more long-distance trade than did the occupants of small houses. The authors claim that

> the five largest houses (1, 3, 7, 18, and 5) occupied during the earliest temporal component at Crooked Ridge Village were associated with 100% of the "Hohokam" ceramics and 100% of the turquoise and marine shell. . . . The . . . results support the hypothesis that large households were most actively involved in the exchange of nonlocal goods [Lightfoot and Feinman 1982:75].

The critical question, of course, is the likelihood that the artifacts deposited in a pithouse were in fact used by the occupants of that house, as the investigators assume. Although Lightfoot and Feinman declined to investigate the formation processes of the pithouse deposits, information in the published reports makes it possible to evaluate the assumption that is the foundation of their analysis. Data from Crooked Ridge Village (Wheat 1954, 1955), a well-reported site that figures prominently in the Lightfoot and Feinman study, serves as an example.

To carry out justifiably the analysis done by Lightfoot and Feinman requires that the pithouses contain predominantly primary or de facto refuse. The McKellar Hypothesis suggests that if primary refuse is present, it will consist mainly of small items on floors. The exotic items are all small and conceivably could be primary refuse. Unfortunately, none of the Hohokam sherds and only one piece each of shell and turquoise were found in "floor" provenience (artifacts in contact with the pithouse floor). The remaining exotic items—3 pieces of turquoise, 14 shell items, and 78 Hohokam sherds—were all recovered in floor fill (the level from floor to about 10 to 15 cm above it) and fill (everything else above floor fill). Moreover, in the fill levels of Lightfoot and Feinman's five large pithouses, only six Hohokam sherds were found—all in one house. It is possible, of course, that the exotic items were originally deposited on floors but were moved upward by disturbance processes. Natural disturbance processes prevalent in this area include tree roots and burrowing animals such as rodents, insects, and worms. It is unlikely, however, that such varied processes could shift uniformly *upward* nearly all the exotic artifacts on the floors. As shown below, the preponderance of evidence suggests other than primary or de facto refuse origins for the fill materials.

As an index to de facto refuse I examined restorable pots and complete manos and metates in floor provenience. Only 6 of 24 pithouses contained restorable pots, and 14 had at least 1 mano or metate. On the floors of seven houses were found three or fewer artifacts. These figures suggest that many houses did not include a very impressive array of de facto refuse, probably as a result of curation behavior or scavenging. The five large pithouses of greatest interest to Lightfoot and Feinman are not atypical. All (except house #18) had at least one whole mano or metate in floor contact; but only two (houses #5 and #7) had pots in floor provenience. Thus, even if the investigators had confined their analysis exclusively to "floor" artifacts, it is doubtful that comparable deposits of de facto refuse, with the possible exception of ground stone, were available from most pithouses.

We may now ask, what is the nature of the fill and floor-fill levels? Joe Ben Wheat, the excavator, assumed but did not demonstrate that the materials had been deliberately dumped or had washed into the pithouses after their abandonments (Wheat 1954:14, 168); that is, he assumed that they were secondary refuse or secondary deposits. Additional evidence to evaluate the fluvial hypothesis is lacking; for present purposes, however, such a test is not essential. It should be noted, however, that the site exhibits sufficient relief to suggest that fluvial processes played a role in filling abandoned pithouses.

The remaining lines of evidence suggest that the bulk of fill and floor-fill items are secondary refuse. In general, these deposits contain a diversity of fragmentary artifacts. In one pithouse, for example, there are 35 sherds from at least 5 Hohokam pots. In addition, pottery types representing several phases are often present in the same pithouse; in one case, the phases span >600 years. Moreover, for the site taken as a whole, fill deposits contain more kinds of artifacts than floors. Of Wheat's 114 fine-grained types for all artifacts (except unworked sherds and restorable pots), 62 are found in floor context and 92 in the fill levels. In the "fill" itself, 87 types are present. However, floor assemblages do exhibit a greater diversity of ground and pecked stone artifacts, suggesting that these sometimes bulky items were deposited as de facto refuse. With their diverse ceramic, bone, and chipped stone artifacts, the fill levels seem to represent mainly artifacts of higher discard rate, which is consistent with the secondary refuse hypothesis.

If the completeness index could be computed for pots in the fill, it would probably produce relatively low values, expectable for some kinds of secondary refuse and for extensively reworked deposits. A completeness index may be crudely approximated for *all* intrusive sherds by dividing the quantity of such sherds (range: 0 to 392) by the minimum number of vessels (MNV) for each pithouse. The number of different types represented by the sherds places a lower limit on the MNV. If one is willing to assume that the intrusive sherds are generally small, then values of this index should go from 1.0 (a vessel represented by one small sherd) to more than 100. The results for all Crooked Ridge pithouses range from 1.0 to 24.5 on the combined fill and floor-fill deposits, with a median of less than 2.0. The index for the five large pithouses varies from 1.0 to 2.0, demonstrating a high degree of incompleteness. These findings suggest that, after the breakage of a vessel, its sherds were widely dispersed over the site, probably as secondary refuse that was extensively reworked. Such a high degree of disorganization can arise through a number of specific refuse disposal and disturbance processes. Future studies of Mogollon pithouse villages should strive to model these processes in more detail in order to establish a credible basis for pithouse dating and other fundamental inferences.

If the above-floor pithouse contents are mainly secondary refuse, then one might expect a relationship between materials in floor-fill and fill proveniences. However, if such a correlation could not be found, there would be some basis for inferring that floor-fill artifacts were indeed laid down independently from the rest of the fill, perhaps as de facto refuse. Examining sherds only, one finds a fairly good correlation ($r = .71$, $p < .05$) between quantity in fill and floor-fill, demonstrating that the "fill" is a single deposit (or multiple deposits) of postoccupational material that has been arbitrarily segmented. Clearly, the fill deposits containing the exotic artifacts are most likely secondary refuse (or secondary deposits) of an unspecified nature and origin. There is no basis to assume, as did Lightfoot and Feinman, that these artifacts were left in a pithouse by its inhabitants.

But what of the relationship the investigators purportedly found between large houses and exotic items? An explanation can be framed in terms of formation processes. The probability that a secondary refuse deposit, such as the fill and floor-fill levels of a pithouse, will contain items of low discard rates (e.g., Hohokam pottery, shell, turquoise) increases with the quantity of refuse deposited (Rathje and Schiffer 1982; Schiffer 1975d). There are grounds for believing that, in a sizable sample of Mogollon pithouses, on the average, big ones should contain more secondary refuse than small ones, and thus more exotic items. Holding depth constant, larger pithouses have a greater refuse-holding capacity and, once abandoned, might become preferred dumping loci. In addition, after the structures decayed (or were scavenged for wood), smaller pithouses would fill in more rapidly by natural processes, reducing their opportunities to become dumps. If the earth that perhaps was placed against the walls and on the roof of these structures contained artifacts, then more such items would come to rest after structural collapse in the fill of larger houses. Finally, because of a greater perimeter, more artifacts should wash into larger pithouses.

Evidence from Crooked Ridge is instructive. Total artifacts in the pithouse fills range from 200 to more than 3,500, with a mean of 1,509, indicating substantial accumulations of refuse. Indeed, two of the five large pithouses (#3 and #5) held in excess of 3,400 sherds. The greatest number of Hohokam sherds came from house #19, a possible ceremonial structure, which contained 3,430 sherds and had the largest floor area of Crooked Ridge pithouses (about 85 m^2, my estimate). Even more suggestive are the mean sherd totals for the eight largest and nine smallest houses: 2,246 and 877, respectively. At Crooked Ridge, at least, there is a relationship between pithouse size and total artifacts in the fill (represented by sherds, which comprise the bulk of the assemblage). Evidently, the hypothesis that the association of exotic artifacts and pithouse size in the Lightfoot and Feinman sample results from differential refuse deposition merits further scrutiny. It is not unlikely that the archaeological pattern found by these investigators is due entirely to formation processes and not to the past behavior of interest.

In this example, published data have provided a basis for coarsely identifying some formation processes of pithouse deposits. Although the exact nature of the pithouse fills is still unknown, we can be sure that as extensively reworked secondary refuse or secondary deposits they do not furnish relevant evidence for the specific research question addressed by Lightfoot and Feinman. If this example is indicative, then extant data may include sufficient traces of formation processes to permit an investigator to ascertain the degree of match between research question and available data (cf. Reid 1975). By identifying formation processes one determines the research potential of particular deposits and sites and, as a consequence, specifies their limitations with respect to particular research questions (Schiffer and House 1977a, 1977b).

CONCLUSION

I almost entitled this paper "archaeology as sedimentology," and it would not have been inappropriate. The first order of business for the archaeologist is to identify the nature of the cultural and noncultural formation processes that created a given deposit or set of deposits. To accomplish this, we may consider artifacts as merely peculiar particles in a sedimentary matrix

(Schiffer and McGuire 1982:252) that potentially have been subjected by cultural and natural formation processes to a variety of mechanical and chemical alterations. By recording the systematic effects, such as size reduction and sorting, damage patterns, and disorganization, investigators can come to appreciate the past agencies that were responsible for the complex arrangements of cultural and environmental materials (deposits) observed today. Knowledge gained from ethnoarchaeology, experimental archaeology, taphonomy, and geoarchaeology contributes importantly to the effort to understand the distinctive sediments encountered by the archaeologist.

At the same time, the perspective elaborated in this paper leads us to view deposits themselves as peculiar artifacts, the characteristics of which must be studied in their own right. Deposits are the packages containing evidence that *may* be relevant to one's research questions; to establish such relevance, however, requires that the genesis of deposits be determined, in terms of both cultural and natural formation processes. For the archaeologist with a large-scale project and scores of inferences to make, the focus on deposits is logical and convenient, for by first identifying their formation processes, beginning in the field, one can efficiently and firmly match research questions to relevant evidence.

The importance of identifying formation processes *before* behavioral or environmental inferences are developed cannot be overemphasized. In far too many cases, the evidence used by an archaeologist owes many of its properties, not to the past phenomena of interest, but to various formation processes. The example of the Lightfoot and Feinman study indicates the perils of failing to identify formation processes. If the latter are identified "up front," using the most sensitive lines of evidence, then the investigator will be able to establish the comparability of deposits and their relevance for the research problems and to choose the most appropriate analytic strategies. On such a foundation are built credible inferences.

Superficially, the directions I am advocating seem to take us farther away from the behavioral and organizational properties of past societies that are so important to contemporary theorists. That is true, but only in the short run. In the long run, enhanced understanding of formation processes permits inferences about past phenomena that have a logical and scientific basis. When any archaeological inference is put forth, the investigator has inevitably made assumptions, usually tacit ones, about the nature of formation processes. These assumptions frequently assert that formation processes have slight effects or have random effects that cancel out each other. More than a decade of work on formation processes has shown, however, that these and similar assumptions are wrong and dangerous. Inappropriate assumptions must be replaced by thoughtful efforts to understand how specific deposits formed. Although much basic research remains to be undertaken, enough information is now at hand to make the rigorous study of formation processes a practical component of all fieldwork and analysis. Until such studies are carried out routinely, archaeologists cannot properly claim any behavioral significance for their inferences.

Acknowledgments. I am grateful to the following individuals for supplying ideas, references, or comments on previous drafts: Neal Ackerly, Christopher Carr, Dena Dincauze, Christian Downum, Donald Grayson, Laura Kosakowsky, Owen Lindauer, Randall McGuire, James O'Connell, Clive Orton, J. Jefferson Reid, Deni Seymour, Pat Shipman, Edward Staski, Glenn Stone, Christine Szuter, Michael Waters, David Wilcox, and Richard Wilk. A very preliminary version of this paper was presented at UCLA and at Colorado State University during the spring of 1982. The many comments and suggestions supplied on those occasions immeasurably contributed to the final product, as did the criticisms of students in my seminar on formation processes at Arizona State University in the fall of 1982. I owe a large intellectual debt for the general orientation of this paper to Stanley South, J. Jefferson Reid, Pat Shipman, and David R. Wilcox. I thank Adam Schiffer for proofreading assistance.

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