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EVOLUTIONARY HUMAN PALEOECOLOGY: CLIMATIC CHANGE AND
HUMAN ADAPTATION IN THE PAHSIMEROI VALLEY, IDAHO, 2500 BP
TO THE PRESENT

University of Washington

PH.D. 1982

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Change and Human Adaptation in
the Pahsimeroi Valley, Idaho,
2500 BP to the Present

by
James Carl Chatters

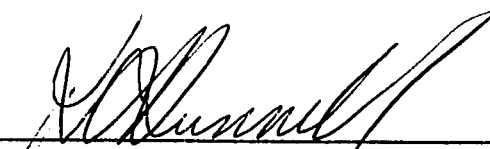
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1982

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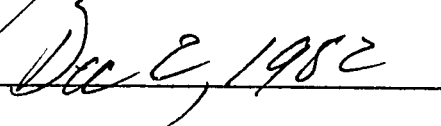


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Toni Peterson and Jenny Elf typed the text in various drafts; Marilyn Morrison and Dianne Semko produced the drawings.

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DEDICATION

To my father, Roy Chatters, who introduced me
to the wonders of deserts and gob piles

and

To Jenny Elf, my mate and our children
Jake and Claire whose love kept me going
when it all seemed so endless.

CHAPTER ONE

Introduction to Evolutionary

Human Paleoecology

"Human history remains so recalcitrantly ideographic because it is the story of a single species - it represents the vicissitudes of an individual of unparalleled flexibility. What theory could encompass it? The history of life has an entirely different nature - it is the story of millions of species all governed by an overarching body of theory - evolution itself."

Stephen Jay Gould (1980:116)

"Culture is the extra-somatic means of adaptation for the human organism."

Leslie White (1959:8)

It has been 20 years since Lewis Binford wrote his influential "Archaeology as Anthropology" (1962), in which he exhorted us to cast off the normative bindings of culture history, take up the scientific method, seek explanations for culture change and thereby contribute to the overall advancement of anthropological theory (also Binford, 1964, 1965, 1968). Many archaeologists, particularly the young, accepted these ideas with an almost evangelical enthusiasm, proclaiming a "new archaeology," an anthropological archaeology (e.g., Redman, ed., 1973; Watson et al., 1971; many papers in Leone, 1972). Viewing the archaeological record as incomplete anthropological data, capable of informing about all aspects of culture systems (Binford, 1962; Plog, 1974; Watson et al., 1971), they set about first to reconstruct prehistoric cultures in as complete a form as possible, often relying heavily on the inter-relatedness of cultural subsystems maintained by systems theory (Binford, 1965) and employing ethnographic analogy as a principal means for inference (e.g., Hill, 1966; Longacre, 1964; Redman et al., 1978; Wilmsen, 1970; Yellen, 1977). These reconstructed "cultures" were then to be the subject of processual study using anthropological theory as a source of explanations. To its practitioners, this new archaeology

was to raise their discipline to the level of a science (Watson et al., 1971), but to others, it was a futile exercise in rhetoric (Bayard, 1969; Sabloff et al., 1973; Hole, 1978).

Today there is a growing realization that the skeptics were correct, that processual goals cannot be achieved by an archaeology designed on an anthropological template (Binford, 1977; Clarke, 1968; Dunnell, 1978a, b, 1979; Meltzer, 1979). Anthropology is primarily a synchronic enterprise that addresses a phenomenon - the ethnographic culture - as a static entity. Even in those rare instances where longitudinal studies have been conducted (e.g., Mead, 1934, 1959), they have spanned periods no longer than the lifetime of an individual, and in no sense attend change at the scale manifest in the archaeological record (Harris, 1968; Plog, 1974, 1977). Anthropological theories of cultural evolution (e.g., Tylor, 1871; White, 1959; Steward, 1955) are perforce typological in nature (Dunnell, 1980; Dunnell and Wenke, 1979; 1980; Yoffee, 1979), and, based on analogies with the developing organism (Blute, 1979), embody the conception of evolution as progressive, directional change from simple to increasingly complex societies. Derived as it is from static pictures of essentially contemporary cultures, anthropological theory is unsuited to the dynamic character of the archaeological record; in fact, to the achievement of any scientific understanding of evolutionary process.

In attempting to apply the anthropological metaphysic to explanations of culture change, archaeologists have been forced to address change from a static, functional framework (Athens, 1977; Dunnell, 1978a, 1979; Meltzer, 1979; Plog, 1977; Schuyler, 1973), in which we are in a real sense forcing a dynamic phenomenon - the archaeological record formed over thousands of years - into a series of static models resembling the ethnographic record. Each of these static units is the description of a "culture" as if it were viewed at a single point in time, when the data from which the reconstruction is drawn may actually represent a period decades or even centuries in length. This step completed, we then attempt to explain the dynamic process of evolution in transactional terms from

a theoretical position drawn from the observations of static phenomena. This mixing of the static with the dynamic has led to a discipline beset by "anarchy, optimism, and products of extremely variable quality (Binford, 1977:9). Not surprisingly, the anthropological approach to archaeology has yet to achieve its goal of explaining cultural change, at any scale.

Due in large part to failure of the anthropological approach archaeology today lacks a coherent theoretical direction (Binford, 1977; Dunnell, 1979; Meltzer, 1979). For evidence of this theoretical uncertainty, one need only consider the diversity of interests expressed in a recent poll (Schiffer, 1978) and at the heterogeneity of thought evinced by the low frequency at which individual papers are cited (Sterud, 1978; cf. Meltzer, 1979).

Recently, South (in Schiffer, 1978), intending to express how the multifarious theoretical concerns of archaeologists were united in a common effort, portrayed archaeology as a giant squid, its many theoretical tentacles engaged in the attempt to subdue a sperm whale, representing the challenge of processual explanation (among other things). I can conceive of no more fitting metaphor for archaeology's current failure to become a scientific, evolutionary discipline; giant squid are a staple of the whale's diet. What we need is a harpoon gun, a body of purely archaeological theory that concentrates on the archaeological record as an independent body of data capable of explanation in its own terms (cf. Binford, 1977, 1978a, b, 1981; Dunnell, 1978a, 1979).

This archaeological record consists only of contemporary artifacts, contemporary relationships between artifacts, and contemporary relationships between artifacts and the biophysical environment. These phenomena are the material entailment of human activity and there is a strong correlation between behaviors performed and the kinds and distributions of artifacts that comprise the record for any segment of space and time. Artifacts and their relationships are thus the outcome of behavior, but they are not themselves fossilized behaviors. The proper subject matter of

archaeology, if we are to achieve our goal of understanding the processes of culture change, is the archaeological record itself.

At least some of the behaviors that have produced the record, and that continue to produce it today, are adaptive. Hence, the archaeological record is at least in part a record of human adaptation. Since Homo sapiens adapts behaviorally at a much faster rate than it does physically, the archaeological record, which is itself the consequence of human behavior, is a proper phenomenon through which to investigate the evolution of human adaptations.

A theoretical approach to archaeology that can effectively address the archaeological record as an independent body of data and potentially achieve a scientific understanding of the processes of change in human adaptations has been developing for some time as two separate lines of thought. Both these lines, the ecological approach and the application to archaeology of Darwinian evolutionism are based on the Whitean conception of culture as humanity's adaptive system, and both have been applied to explain the processes of change. It is my contention that neither approach alone will achieve this goal, but that in combination they may raise archaeology to the level of an evolutionary science on a par with, if not superior to modern paleontology.

Ecology and Evolutionary Theory in Archaeology

The importance of ecology to today's archaeology is apparent in Schiffer's (1978) survey of theoretical interests and the tables of contents of most journals and books, especially those produced by Academic Press. Ecological approaches to archaeology have recently been summarized by Jochim (1979a; cf. Willey and Sabloff, 1980) and it does not serve my purpose here to recite the complex history of this subfield. In general, however, the ecological concerns of archaeologists have developed from the simple interest in environmental context and the enumeration of the plants and animals used by prehistoric peoples into a sophisticated applications of models derived from the theory of biological ecology

(cf. Starna, 1981). Optimization models, particularly those based on variants of optimal foraging theory (e.g., Bayham, 1980; Beckerman, 1980; Jochim, 1976, 1979a; Perlman, 1980; Styles, 1981) and microeconomic theory (e.g., Christensen, 1980; Earle, 1980; Keene, 1981) have become increasingly popular approaches to reconstructing the relationship between prehistoric human populations and the ecosystems of which they were a part.

Ecological models are mechanistic; that is, they describe the operation of an ecological system, focusing on the relationship of the human organism to its living and nonliving environments. These models, often too precise for each variable to be measured in the archaeological record (e.g., Earle and Christensen, 1980; Jochim, 1976), are occasionally used to consider how a deviation in the values of environmental variables may precipitate an adaptive response, reflected as change in the archaeological record (e.g., Croes and Hackenberger, 1981; Fitzhugh, 1975; Hackenberger, n.d.). However, these models generally address the question of how a cultural system maintains a homeostatic relationship with a fluctuating environment, and do not attempt to model the change from one state of the cultural system to another. In fact, as mechanistic models - functional models, they are capable only of identifying the proximate cause of an adaptation (how it operates to maintain the human organism) and are inappropriate means for explaining the process of change (Athens, 1977; Burnham, 1973; Dunnell, 1979; Dunnell and Wenke, 1979). This is especially true of change that is generated from within the cultural system. Theories that address ultimate causation, that invoke processes by which one state of a system is transferred into another must be applied for a complete understanding of cultural change.

In the biological sciences, which are also concerned with the question of adaptation, organismic change is manifest in differential reproductive success (differential fitness) between one variant of a species and another. Differential fitness is a product of interaction between living variants and their environments.

This process is natural selection and is the foundation of Darwinian evolutionism.

Increasingly, archaeologists and social anthropologists are accepting that culture, as the adaptive system of Homo sapiens is analogous to the phenotypes of other organisms and that, therefore, cultural change may occur through a process at least analogous to natural selection (Blute, 1979; Dunnell, 1978a, 1980; Dunnell and Wenke, 1979, 1980; Durham, 1976; Plog, 1977; Richerson, 1977; Richerson and Boyd, 1979). Although others, both within archaeology (Kirch, 1980; Raab, 1977) and from the biological sciences (Gould, 1978) disagree, the idea has also been favorably considered by biologists (Lewontin, 1978). The arguments in favor are compelling.

Darwin's (1859) theory of descent with modification, which we now call natural selection, is not restricted to genetically producing organisms. The theory applies to any self-replicating mechanism (Pianka, 1974), providing three conditions are met.

1. The mechanism must spontaneously generate random variability that is expressed in the phenotype.
2. It must have some means by which variation can be transmitted between generations.
3. Some variants must contribute directly to the mechanism's reproductive success, thereby having an impact on the frequency with which they are expressed in subsequent generations (differential fitness).

The process whereby the differential fitness of variants is effected through interaction with the mechanism's environment is natural selection. Blute (1979), Dunnell (1980) and Richerson and Boyd (1979) argue effectively that these criteria are met by cultural behavior.

The behavioral phenotype of the human organism (Dunnell, 1980) which we call culture, is transmitted from one generation to the next through the process of socialization and is therefore, heritable. However, heritability also takes an intra-generational form, through the imitation by adults of the behavior patterns of others. This secondary mode of inheritance, and the impression that

individuals rationally select modes of behavior they find most effective, has led some to suggest that culture change is effected by individuals making choices, with a complete understanding of the consequences of their actions (e.g., Bennett, 1976; Dumond, 1972; Christenson, 1980; Earle, 1980; Hastorf, 1980; Jochim, 1976, 1979a; Kirch, 1980). This conception assumes that people have complete information about the probable outcomes of their choices, which is false (cf. Hespeneheide, 1980). How many of us have chosen between alternative courses of action, after calculating carefully the probable outcome of each, only to learn to our dismay and economic loss, that we were wrong? It is not that the original choices of behavior are rational (indeed they may often be), but the reproductive success those behaviors confer that affects their frequency of expression in future generations.

Recognition that there are two modes of inheritance has led to disparate ideas about how fitness is expressed in the cultural realm. Dunnell (1980; cf. Durham, 1976), holding a strongly Darwinian viewpoint maintains that the fitness of a cultural phenotype is expressed in the biological offspring of the bearer, i.e., reproductive success in the physical sense. Taking a slightly different, though not contradictory position, Richerson and Boyd (1979; Richerson, 1977) suggest a concept of intellectual fitness, the relative number of individuals who, through socialization and imitation express a particular pattern of behavior which is an auxiliary to the biological fitness as expressed by Dunnell (1980; cf. Alland and McKay, 1973; Kirch, 1980). Both positions have merit.

Whether the initial generation of behavioral variability is random is also a matter of some dispute. There are two schools of thought, which for simplicity can be called the Lamarkian and Darwinian. The Lamarkian school holds that variation results from the rational quest for solutions to problems posed by the environment (e.g., Christenson, 1980; Kirch, 1980; cf. Gould, 1979a), whereas Darwinian thought maintains that variation is generated randomly and that much of it is quickly eliminated by selection (cf. Dunnell,

1980; Dunnell and Wenke, 1979; Plog, 1977). Blute (1979), citing patent office records, business statistics and academic data, shows that few new intellectual and technological developments are successful, making a strong case for the Darwinian position. Only in retrospect do advantageous solutions appear to have been rationally invented (Dunnell and Wenke, 1979).

The third criterion, differential reproductive success is also met by cultural adaptation. As the most malleable aspect of the human phenotype, culture is that part of the organism that is most "visible" to selective pressures impinging on the human population. Consequently, the life or death or, more often, the reproductive success of a human population will be at least partially, if not primarily a function of its behavior. The more closely a pattern of behavior is adapted to its environment, the higher will be the reproductive success of the human actors relative to the people with less adapted behavioral phenotypes (cf. Dunnell, 1980).

Addressing the question of ultimate cause, natural selection does provide for evolutionary explanations of cultural change (e.g., Chatters, 1981a; Stutenmund, 1981), but it does not embody the means for testing those explanations in a non-tautological manner. The logical implications of an hypothesis that adaptation Y replaces X as a consequence of natural selection are that Y appears as a variant adaptation in Time 1 and during successive Times 2, 3 ...n becomes more increasingly prevalent, hence more fit than its predecessor. Indeed, if these conditions are met, we might conclude that natural selection is the ultimate cause of the change. What have we learned? Natural selection implies increased fitness and increased fitness is taken as evidence that natural selection is operative. Having already concluded that natural selection is an important process of cultural evolution, can we not thus proceed to identify it as the cause of any change observed in the archaeological record?

It is evident that explanations based on evolutionary theory alone would be overly generalized and to a great extent tautological

(to be sure, no one has suggested we pursue this approach), whereas ecological models are incapable of providing evolutionary explanations. The two are, in fact, complementary; ecological theory supplies an understanding of the relationship of a human adaptation to the environment showing the proximal cause of that adaptation; evolutionary theory supplies the ultimate cause of change from one form of adaptation to another (Dunnell, 1979; cf. Stutenmund, 1981). The two are therefore inextricably joined in an effective test of evolutionary theory. To paraphrase Valentine:

Clearly the relationships of organisms and their environments are critical to determining the success or failure of a modification whether behavioral or structural to establish itself and endure, and these relationships are the province of ecology. Since ecology is of fundamental significance in determining the pathways of evolution, it is logical to join the studies of ecology and [evolution] into a single discipline in order to investigate the history of life [or the history and processes of culture change]. The interrelationships are intimate. (1973:12)

Ecological theory provides us with the means to understand relationships between variant adaptations and their environments during successive intervals of time and to measure the relative efficiency of each adaptation for acquiring resources, avoiding predators and attracting a mate; things necessary to survival and successful propagation. It thus allows us to perceive the selective pressures that impinge upon the variants and that confer advantage on one variant over its competitors. The ideas of heritable variation and differential reproduction are components of the ultimate cause; interaction among the organisms and their environment is the proximate cause of evolutionary change. Whether we are considering the evolution of physical phenotypes of horses or the behavioral phenotypes of people, ecological and evolutionary theory are inseparable.

Evolutionary Human Paleoecology

We now have the means by which the theoretical uncertainty of the archaeological discipline may be resolved, through acceptance

of the following concepts: (1) the archaeological record, not the precise behavior it represents, is the proper subject of study, (2) at least part of that record is the manifestation of adaptive behavior, (3) as a heritable adaptive mechanism, culture is subsumed under general theories of evolution and ecology, and (4) any evolutionary explanation or test of evolutionary theory must have both natural selection and ecological theory as its components. This new form of archaeology, and it truly is new in the sense of being a distinct paradigm from the anthropological school of archaeology (cf. Meltzer, 1979), is now being developed (Binford, 1977; cf. Dunnell, 1978a, 1978b, 1979, 1980; Jorde, 1977; Stuenkel, 1981), with a theoretical base deduced from evolutionary and ecological theories, but constructed of variables actually observable in the archaeological record (Dunnell, 1979). I call this approach evolutionary human paleoecology; the study of human behavioral evolution in terms of ecology and the theory of natural selection.

To apply this approach to archaeological phenomena, we must first construct the necessary archaeological variables, of which five are integral. We must, first, specify the entity of which we wish to study the evolution and, second, be able to distinguish between the adaptive and non-adaptive attributes of that entity (since the latter cannot be related to natural selection). We must then define the three most important variables of the process. Natural selection is expressed through differential fitness of variant phenotypes which results in part from the effectiveness of the phenotype's interaction with its environment. The sum of all interactions between an organism and its environment is its ecological niche (Hutchinson, 1957). The third through fifth variables are, therefore, variability, fitness and niche. Thus, to investigate the evolution of cultural adaptations in terms of natural selection, we must define the subject of study in archaeological terms, be able to assert that our subject is related to adaptation, be able to perceive variations in that subject and determine the niche of each variant in order to understand the cause of observed changes in its relative fitness.

In the following paragraphs I present initial formulations of these five variables for archaeology, presented as answers to five questions:

1. What evolving entity is observable in the archaeological record?
2. How do we distinguish adaptive components of the archaeological record from those that are adaptively neutral?
3. How is behavioral variability generated and how are we to observe it in the archaeological record?
4. How are we to measure fitness archaeologically? and
5. How can archaeologists identify the niche of a human population?

Many of the answers to these questions are already available in the literature; I have posed my own answers for others.

What evolving entity is observable in the archaeological record? Certainly, that entity cannot be individual behavior, which we cannot observe, nor can it be the archaeological manifestations of individual behavior. In spite of efforts to the contrary (cf. Hill and Gunn, eds., 1977), we are capable only of observing the mean products of collective behavior (Binford, 1981; Cordell and Plog, 1979; Plog, 1977). Hardesty (1980) suggests that our entity is the system of production applied by the human society, but since this is only indirectly inferred from the archaeological record, what we are really observing is the material entailment of such systems; the patterned distribution of classes of artifacts, which I call the adaptive pattern.

When Reher (1977:14) posits that "an evolutionary sequence can be abstracted from various characteristics of the organizational complexity of prehistoric groups as they are reflected in the technological leavings of the archaeological record," he is talking about social organization inferred from intra-site complexity. However, his suggestion that an evolutionary sequence can be seen in the technological leavings or the archaeological record is valid, and can be extrapolated to incorporate the entire record left by a

human population over a period of years. That record represents, at least in part, the evolution of human adaptation to the social and biophysical environments.

Much of human behavior is associated with the acquisition and use of resources. Since resources come from the environment and in the sense that adaptation of an organism is defined as conformance with its environment, these aspects of human behavior are adaptive (cf. Kirch, 1980). This adaptive behavior often entails the use of tools and facilities and results in modifications of the environment at varying scales, from deformation of the landscape to deposition of natural objects in artificial positions. More simply, adaptive behavior results in the use and production of artifacts.

Resources are unevenly distributed over the environment in space and time and may also, through human organization, be differentially processed and used over the space of a living site. Different tools and facilities may also be used in different ways to acquire, process and use each of these kinds of resources and may result in different forms of environmental modification. Given these two concepts, if we assume tools, facilities and other by-products of human activity to be lost, discarded or created most often in the environments where the associated activities were performed, then we may conclude that the differential distribution of classes of artifacts over the environment of a site or region is the empirical entailment of human adaptive behavior (Binford, 1964; Binford and Binford, 1966, 1969). We thus have, in a real sense, a

fossil record (that) may be read in the quantitatively variable spatial clusterings of formal classes of artifacts. We may not be able to state . . . what specific activities resulted in the observed differential distributions, but we can recognize that activities were differentiated and determine the formal nature of the observed variability. (Binford, 1964:158)

Therefore, the distribution of artifacts, at whatever scale, over the environment, whether artificial or biophysical, results from the repeated adaptive behaviors of human beings (cf. Cleland, 1976). This artifact patterning is thus an adaptive pattern. In

the terms normally used by archaeologists, an adaptive pattern is comprised of those aspects of the archaeological record which entail the patterned relationships between functional classes of artifact and the environment. This includes land use patterns (Dancey, 1973; see Chapters 5 and 7, below), settlement patterns at all scales (cf. Parsons, 1972; Trigger, 1967) and the technologies used to exploit and utilize specific resources. Differential distributions of commodities, such as obsidian, metals and finished goods, which are interpreted to represent exchange systems, (cf. Earle and Erickson, eds., 1977) may also be thought of as adaptive pattern (although they also represent a dimension of the ecological niche of human groups).

Using ethnoarchaeological data from Australia, Hayden (1978) argues that interassemblage variability in artifact classes cannot be used as an indicator of differential activity performance. Hayden found that few or no non-perishable tools remained after the performance of most resource exploitation activities, and that, when lithic debris did remain, it usually occurred at densities too low for archaeological visibility (Deetz, 1968). In addition, those lithics that did remain from activities such as butchering were often used, unretouched flakes or other artifacts that were not, in his terms, activity specific and therefore failed to accurately reflect activity performance.

Hayden is working from three premises, none of which is correct.

1. Archaeologists wish not only to observe the patterns of human adaptation, but also to reconstruct the actual behavior of prehistoric people.

2. Formed tools (those with shapes intelligible to the average ethnographically aware archaeologist) are the only kind of "activity specific" artifacts.

3. Archaeologists always work with buried deposits, in which case the potential for discovery of an artifact deposit is proportional to artifact density (Schiffer et al., 1977).

I have already argued that the total reconstruction of human behavior has not proved to be an effective approach to solving problems of cultural process. Further, as Binford (1964, 1981), who Hayden is actively criticizing, points out, the precise reconstruction of behaviors is not a necessary outcome of studies in artifact distribution. Certainly, as I shall expand upon later, archaeology can proceed effectively as evolutionary human paleoecology without recourse to reconstruction of the kind Hayden seems to prefer, and would in fact be damaged by its use.

Hayden's (1978) implication that formed tools are the only artifacts that reflect activity performance is surprising, considering his work with lithic use wear (Hayden, 1979). It is, in fact, wear, rather than tool shape that most closely conforms to the use of an object (Dunnell, 1978b; cf. Semenov, 1964; Tringham et al., 1974; other references in Chapter 5). Thus, the unretouched flakes used in butchering, though not shaped, might be worn differently from flakes or retouched tools used for other purposes.

That archaeologists always work with buried objects is also becoming less true by the year. As Lewarch and O'Brien (1981) have shown, the discipline is turning increasingly to surface data, especially where adaptive patterning is the subject of research (e.g., Chatters, 1980a; Dancey, 1973, 1974; Goodyear, 1977; Raab, 1977; Thomas, 1971a, 1973). In fact, as any experienced field archaeologist will attest, buried deposits are rare outside settings where alluvial and aeolian deposition are extreme. Because environments with low potential for artifact burial contain natural resources that often differ from the resources of alluvial environments, and since people often exploit these resources heavily (cf. Hunn and French, n.d.; Ray, 1932; Steward, 1938), these exploitation activities not only leave artifacts, they leave them on the surface, where objects are more readily visible. It is these surface artifacts, with their ready visibility even at low densities (cf. Chatters, 1980a) that can most effectively be exploited by archaeologists to ascertain patterns of activity performance.

Finally, in his effort to disprove Binford's interpretation of interassemblage variability as a reflection of differential activity performance, Hayden has unwittingly supported that position. In Hayden's (1978) study, different activities did indeed leave artifact residues (discarded tools, environmental modifications like tree stumps) that were distinctive and those assemblages exhibited patterned distributions over the landscape. Certainly, his assertion that some activities leave no nonperishable residue is valid; not all behavior leaves traces in the archaeological record. We can never be certain the patterns we observe reflect the totality of human adaptations, but we have long been aware of that fact.

For his part, Binford (1977, 1978a, b) has proceeded to compile ethnoarchaeological information which also demonstrates a correlation between activity and artifact distributions. To be sure, studies of artifact taphonomy (cf. Schiffer, 1972, 1976) point out that objects do not always remain where dropped. In general, however, especially when we consider patterning at a scale above that of site, artifact distributions (adaptive patterns) can be taken as a reflection of the patterned behaviors that produced them.

There is also a problem of scale that we must address in dealing with the adaptive pattern concept. Cleland (1976) asserts that the minimal unit for consideration is the total subsistence round of a human group. I disagree, for several reasons. First, there are, to date, few complete constructs of prehistoric patterns of adaptation that cover the complete seasonal round (Ford, 1977). In fact, Hayden's (1978) work shows that artifact patterns representing the totality of adaptive behavior are beyond the reach of archaeologists simply because some activities leave no trace. Second, because we can never be certain whether two or more sites are the product of a single social group, reconstruction of the total subsistence round for one social group is an impossibility. What we work with, rather, are the material entailments of aggregate behavior (cf. Binford, 1981; Cordell and Plog, 1979; Plog, 1977). Therefore, to place an artificial lower limit on the scale at which

adaptive patterns are observed is unfounded. Finally, I am concerned with changes in adaptive patterns and the evolution of adaptive behavior they represent. The adaptive patterns concept subsumes the totality of adaptive behavior reflected in our record, nothing more. These patterns exist at many scales, the artifact (wear pattern), the assemblage (technologies), the site (community pattern) and region (settlement pattern, land use pattern, exchange systems), and at each scale these patterns are capable of change that may be explainable in terms of evolutionary human paleoecology. We might, thus, investigate the changing fitness of variant patterns of adaptation at many scales, from technologies to complete systems.

Therefore, adaptive patterning, the material manifestation of an evolving entity that we observe in the archaeological record, consists of the patterned distributions of artifacts at any scale with respect to the artificial and biophysical environments.

How do we distinguish adaptive components of the archaeological record from those that are adaptively neutral? Whether we are considering genetically or culturally inherited phenotypes, not all characteristics exist because they are adaptive (Dunnell, 1978a; Gould, 1980; Gould and Lewontin, 1979; Lewontin, 1974, 1978, 1979). In archaeology, we identify nonadaptive variation as stylistic, adaptive variation as functional, and distinguish between the two on the basis of their spatial and temporal distributions. Functional characteristics correlate with environmental variables; style behaves randomly (Dunnell, 1978a).

How is behavioral variability generated and how are we to observe it in the archaeological record? As is the case with biology, wherein molecular geneticists fill the role (e.g., Lewontin, 1974), the first part of this question must be answered by observers of contemporary behavior (e.g., Blute, 1979). The second part is a purely archaeological problem. Starting with Binford (e.g., 1962, 1965), students of culture process have recognized that the system of units devised by culture historians for observing time-space distributions is inappropriate to an evolutionary science. Now,

with explicit recognition of natural selection, we can better articulate why this is true. Natural selection acts on phenotypic variation, and, when we consider culture as a series of static units we make that variation (Cordell and Plog, 1979; Plog, 1974). This makes it impossible to discern how long prior to its period of dominance a particular component of an adaptive pattern may have existed and precludes our analysis of the selective advantage of one variant relative to others under various environmental conditions.

To effectively measure variation in the archaeological record, we must first discard the phase concept and cease to describe the adaptation of the people of previously constructed phases. Beginning anew, we should first create the components of adaptive patterns, then observe the distribution of these components in time relative to each other and to the natural environment. Only then can we perceive the development and relative fitness of variants, ascertain the impact of environmental conditions on them and consider the effects they have on the fitness of an adaptive pattern as a whole. This approach is now increasingly followed, especially in conjunction with studies of settlement and land use pattern (e.g., Benson, ND; Bettinger, 1979; Chatters, 1981b; Cordell and Plog, 1979).

How are we to measure fitness, archaeologically, especially when there is some controversy over whether intellectual or biological fitness is primary in cultural evolution? Some attempts to answer this question have already been made. Hardesty advocates "relative productivity of a production system" (1980:13) as a measure of fitness. However, he does not specify how the latter might be quantified, nor its relationship to efficiency, and I fail to see how fitness might be measured thusly in the archaeological record. Alternatively, he offers persistence of an adaptation ("productive system"), a concept that Kirch (1980) also seems to favor. Persistence is also an inappropriate archaeological measure, as it does not conform to the meaning of fitness in evolutionary theory. Persistence, rather, is a measure of adaptiveness (Pianka,

1974), the conformation of an organism to its environment, which is related to but not an equivalent of fitness (Lewontin, 1978).

In biological usage, fitness is a relative concept and is measured in comparison with other, competing phenotypes, the most numerically superior variant at any one time being considered the most fit. This concept requires a close relationship between genetic material and the expression of that genetic material in the form of a living entity. For every set of genetic material there is (excepting monozygous twins) only one individual expressing a particular phenotype. If we accept Keorper and Stickel's (1980) conception that ideas are homologous with genes in both the transmission of information between people and as the proximate cause for specific patterns of behavior, we may likewise conceive of fitness as the proportionate number of people expressing alternate behavioral forms. For each set of ideas there is only one actor. Thus we might in the ethnological present measure fitness in the relative number of people exercising each particular mode of adaptation.

When we move from the ethnographic to the archaeological realm, however, this one-to-one relationship between ideas and actors becomes difficult, if not impossible to measure. Unless we are interested in stylistic variants of behavior (e.g., Hill and Gunn, 1977) archaeologists are not capable of identifying specific artifacts with individuals (cf. Binford, 1981), nor can we accurately measure human populations from the archaeological record (Hassan, 1981). That record consists of the material entailments of human activities, and, since each human actor may perform a specific activity more than once, and other activities are the result of group interaction, there is no longer a one-to-one relationship between the information (ideas) and the measurable result of their physical expression: artifacts.

A solution to this dilemma can be achieved if we recognize the archaeological record as a product of dynamic, collective behavior (Binford, 1981; Plog, 1977). Given this understanding, we may then assume that the relative material expression of variant forms of

adaptive behavior (adaptive patterns) is proportionate to the relative number of human actors expressing each variant. Thus we may consider the relative abundance of alternate tools, technologies or complete adaptive patterns as a measure of the fitness of the behaviors they represent. For example, broad-neck and narrow-neck projectile points represent distinct hunting technologies, at least in some areas (Chatters, 1981a), and may be considered as representatives of alternate technologies the practice of one of which may compete with the practice of the other (atlatl and dart versus bow and arrow hunting, cf. Thomas, 1978a). If narrow-necked projectile points are more common than broad-necked at Time 1 and less common at Time 2, the technology they represent has become less fit with time. This measure is archaeological fitness.

This approach to archaeological fitness has its flaws, to be sure, not the least of which is the problem of counting. From ethnographic observation and common experience we know that some activities are collective, others individual; some may be performed once in a season, year or generation (cf. Steward, 1938), others repeatedly. Clearly, individual activities and oft-repeated activities will always be numerically superior to their collective alternatives. Group activities, such as bison kills (cf. Frison, 1978; Reher, 1977) may also be thought of as multiples of individual activity and may represent a higher number of such hunting activities than individual kills performed by the same populations. To further complicate matters, collective activities will be more likely to leave behind enough artifacts to be archaeologically visible (Deetz, 1968; Schiffer et al., 1977) than will individual activities of a similar nature (cf. Hayden, 1978), and will be over-represented in archaeological data. Therefore, because we have no means for determining the actual number of times individual activities of competing types have been performed, and will never develop those means (short of a time machine, and then we would be obsolete), archaeological fitness is an imprecise concept. Consequently, we cannot make reference to fitness of a given adaptation

during any single segment of time, but should only use the concept when considering change in the relative abundances of adaptive patterns or the components thereof (the solution is common to problems of quantification in many of the paleosciences; see Chapters 9 and 10). Reher (1977; Reher and Frison, 1980) advocates a similar approach to test his model of adaptive processes on the shortgrass plains, particularly in reference to collective versus individual hunting patterns.

How can archaeologists identify the niche of a human population? To correctly measure the selective advantages of adaptive variants under differing environmental conditions and thereby to understand the proximate causes of specific episodes of cultural change, we must understand the relationship of an adaptation to its environment. This relationship is treated in ecology under the label of ecological niche. The niche concept has long been a subject for debate in ecology (cf. Pianka, 1974), and its application to anthropology (e.g., Hardesty, 1972, 1975, 1977) and archaeology (Christenson, 1980; Hardesty, 1980; Kirch, 1980) have been considered in some detail. It is not my intent to summarize nor contribute to this debate, merely to point out that archaeologists already have at their disposal the means for observing and quantifying the ecological niches of human populations.

For a definition of the niche concept, I follow Hutchinson (1957, 1965) as simplified by Pianka (1974). The ecological niche of an organism is an N-dimensional hypervolume enclosing the complete range of conditions under which that organism can successfully replace itself (Hutchinson, 1957). This model is too abstract to be of practical value, especially in archaeology, which cannot observe the full range of interactions between people and the environment. Niche is therefore generally reduced to the three most important dimensions: space, time and resources. Space is the habitat of an organism; time, its patterns of diurnal or annual activity, and resources are the foods, nutrients and raw materials required. Two other dimensions, competition and cooperation may

also be important to cultural adaptation (cf. Blanton, 1976; Carniero, 1970; Kowalewski, 1980; Sanders, 1968, 1977; Sanders and Price, 1968).

The human habitat is identified through the distribution of artifacts in space (e.g., Bettinger, 1977; Chatters, 1980; Dancey, 1973, 1975; Dunnell and Dancey, 1980; Goodyear, 1977; Raab, 1977; Streuver, 1968a; Thomas, various). Time, at least the season of year different habitats are utilized or resources acquired, is the pervue of seasonality studies (e.g., Monk, 1981), and we learn of resource utilization by the analysis of floral (e.g., Dimbleby, 1967; Ford, 1979; J. Renfrew, 1978) and faunal remains (e.g., Casteel, 1976; Chaplin, 1971; Gilbert, 1973) and inorganic artifacts. Coprolite analysis (e.g., Callen, 1967; Fry, 1970) and the isotopic content of bone (e.g., Bender et al., 1982; Van der Merwe and Vogel, 1978, Vogel and Van der Merwe, 1977 [Carbon 13/12 ratios]) can both provide evidence of the actual resources and the kinds of resources (respectively consumed as food. Two other approaches to the resource niche, site catchment analysis (e.g., Raab, 1977; Roper, 1979) and ethnographic analogy (Bettinger, 1977, 1979; Thomas, 1971, 1973; Williams et al., 1973) are less reliable. Both are actually hypotheses about resource utilization based on assumptions about past human behavior (Roper, 1979) and should be tested with actual data (Fitzhugh, 1975; Madsen, 1981). Intraspecific competition and cooperation are less readily measured, although exchange systems are one manifestation of the latter (e.g., Earle and Erickson, 1977).

Archaeologists thus have or are beginning to develop the means for identifying the niche of human populations and can effectively model the interaction between human adaptive patterns and their environments. The matter of niche analysis is further discussed in Chapter 2.

Answers to the above questions are essential to the development of archaeology into evolutionary human paleoecology, but there are other questions that we may be able to answer once these basic variables have been constructed. Some, such as "to what extent do

the components of a human adaptation form a coadapted whole that resists change?" which are now posed by biologists about the living organism (cf. Carson, 1975) will have to be answered by students of contemporary behavior. Other problems are the perview of archaeology. For example, we may consider the importance of such evolutionary processes as drift, speciation and convergence and their utility for explaining cultural change. In fact, increasing numbers of investigators are applying these concepts. Ammerman (1975), attempting to explain the development of agriculture and McGhee (1976) looking into Paleoeskima prehistory have both advanced drift as an explanation (cf. Fitzhugh [1976] for another example of drift discussed in another context). Mayr's (1963) model of allopatric speciation was the basis of Binford's (1968b) hypothesis of post-Pleistocene adaptations and Snow (1981) considers an analog of speciation to account for sudden development of new adaptations in the Northeastern U.S. Finally, the development of similar adaptations to the same kinds of biophysical or social environments, a form of convergence in the cultural realm, is an increasingly popular field of study. Adaptations to coastal environments (e.g., Stark and Voorhies, 1978; Whitlam, 1981), high altitudes (Wright et al., 1980), riverine environments with anadromous fish (Schalk, 1977) and the maritime arctic (Fitzhugh, 1975; McCartney, 1975), and the evolution of state societies (Blanton, 1976; Carniero, 1970; Flannery, 1972; cf. Wenke, 1981) may all be examples of convergent evolution. While some authors persist in seeking a single set of processes by which similar developments occur (e.g., Hayden, 1981; Santly, 1980), there is increasing awareness that analogous but unrelated adaptations to similar environmental conditions result from strong selective pressures acting to limit the number of successful strategies (e.g., Blanton, 1980; Fitzhugh, 1975; McCartney, 1975). Acceptance of natural selection as a cultural process may redirect studies of specific modes of environmental adaptation toward investigations of the constraints imposed by various kinds of ecosystems. The work of Schalk (1977) is a step in this direction.

Natural selection may also solve another problem related to convergence: why do certain forms of adaptation develop in a kind of environment in some parts of the world and not in others. Gary Wright (Wright et al., 1980; Wright and Miller, 1976) has asked this with regard to sheep domestication, which developed in Asia but failed to occur in the North American Rockies. Why weren't sheep domesticated in America? The answer, based on natural selection, an opportunistic process acting on randomly generated variability, is: "It did not" (Cartmill, 1981; cf. Slobodkin, 1968).

Summary. One of archaeology's goals has long been to develop a scientific understanding of the processes of cultural change. It is now evident that those goals are not yet reached and cannot be achieved through application of a metaphysic that conceives archaeology as the past tense of anthropology. Although this failure has thrown the discipline into theoretical disarray, there is today a strong materialist trend manifest in the increasing application of ecological theory and scientific evolutionism which can potentially be developed into a truly evolutionary science of culture change. That new science, evolutionary human paleoecology, would be comprised of a general theory deduced from biological ecology and Darwinian evolutionism and applied to the archaeological record as a complete body of data. To effect this application, we must first construct theory made up of variables actually observable in the archaeological record. I have made a preliminary attempt to construct those aspects of theory that I consider to be integral: the adaptive pattern as material manifestation of an evolving entity, the distinction of adaptive from nonadaptive variation, the perception of variation in the archaeological record, an archaeological measure of fitness, and identification of the human niche. Certainly, in the future, these first approximations will be modified and other components will be added.

Evolutionary human paleoecology is not a long way off. As I have shown, many of the tools for its study have already been

developed or can readily be developed from existing method and theory. Using these tools we can now proceed to investigate the processes of cultural change as those changes are manifest in the archaeological record. We may also potentially contribute to evolutionary science as a whole through the evaluation of competing aspects of existing theory and the generation of new ideas. Whether our concern is with explaining culture change or evaluating general theory, it is essential that the means exist for identifying the causes of specific evolutionary events. It is in this realm that evolutionary human paleoecology may play its most important role, for no other paleoscience has as complete a record of evolutionary change as that of archaeology.

The archaeological record is no less useful than paleontological data (cf. Gould, 1980) for evaluating some components of a general theory of evolution. Because it is so much finer grained in a temporal sense and comprises so many evolutionary events in a short period of geologic time and because the vicissitudes of geologic time have not yet taken such a toll as they have on the fossil record, this archaeological record can provide data for more accurate studies of individual episodes of change in a self-replicating, adaptive mechanism. Whereas paleontologists (or paleobiologists) must rely heavily on analogy to infer the niche and environment of most organisms (Ager, 1963; Laporte, 1968; Valentine, 1973; Cf. Kitts, 1974), archaeologists can measure these variables directly (see Chapters 2, 8-11). Because we can investigate evolutionary events relying solely on empirical data, rather than inference, the evaluations archaeologists provide for various tenets of evolutionary theory will be more parsimonious and hence, more robust.

Problem

Conceived as evolutionary human paleoecology, archaeology is the scientific study of cultural change using theory drawn from

ecology and Darwinian evolutionism and focussing on the archaeological record as a phenomenon capable of explanation in its own terms. Because this archaeological record is so complete, it is possible from this theoretical position to evaluate evolutionary theory by investigating the relationships between the selective pressures that impinged on a human population through the interaction of people's behavior with their environment, and changes in patterns of adaptive behavior as they are manifest in the archaeological record. From such observations we may then proceed to identify the causes of the cultural change, measure the tempo of change and understand the mode or modes by which cultural evolution occurs. In addition, because the data are derived directly from the archaeological and paleoenvironmental records, the methods and findings of evolutionary human paleoecology may be applicable to all products of human adaptive behavior, whether produced 25,000 years ago or tomorrow.

My purpose in the body of this dissertation is to develop a method for identifying the causes of individual episodes of cultural change, thus producing data that are necessary to the evaluation of evolutionary theory as well as to the understanding of culture history itself. The method I present concentrates on the relationship between climatic and cultural change, but with minor modifications, it should have a more general applicability.

I demonstrate the utility of this method by examining the archaeological record of the Pahsimeroi Valley, Idaho for examples of change in adaptive patterns, then proceed to investigate the processes that caused those episodes of change.

CHAPTER TWO

The Relationship Between Human Adaptation and Climatic Change: A Method

If archaeologists are to develop explanations of cultural change using the concepts of evolutionary theory, whether of a general sort or applying exclusively to human behavior, we must be capable of observing the evolutionary process in specific instances of cultural change. That is, we must be able to observe the event sequences that comprise change in patterns of human adaptation and to identify the causes of those events for each episode of change. This kind of effort requires information on three general topics, including: (1) the history of an evolving entity, (2) the niche of that entity before, during and after change occurs, and (3) the effective environment of the entity, also before, during and after change takes place.

When observing the history of an evolving entity, we must be certain of measuring change in adaptive behavior. Non-adaptive activities are not directly subject to natural selection (Dunnell, 1978b), although the ability to generate or engage in them may be. In archaeology, we work with a record in which the non-random environmental distributions of certain artifact and settlement classes, the adaptive pattern, constitutes the material entailment, or fossil of adaptive behavior. We can measure changes in that behavior as shifts in the archaeological fitness of these patterns and their components (see Chapter 1). Therefore, it is also important that our methods permit the recognition of variation in the archaeological record, lest we be unable to observe changing fitness and fail to ascertain the role of natural selection in an episode of change.

Because it represents the articulation between an evolving entity and its environment, niche is an indispensable component of

an evolutionary study. It is through the niche (by definition) that we identify the points of articulation between the evolving entity and its environment and thus identify the source of selective pressures acting on that entity. Those aspects of the biophysical environment that also comprise the niche of an entity constitute its effective environment. When the effective environment changes, selective pressures acting on variant adaptive patterns also change, thus altering the variants' fitness and effecting change in the archaeological record.

Actually, changes in archaeological fitness can occur in at least two modes: Mode 1) by the inception of new, immediately more competitive variants which more or less readily replace established variants (the speed depending on the degree of selective advantage for each variant, cf. Fisher, 1930; Strickberger, 1968) or Mode 2) through changes in the fitness of coexisting variants that results from a shift in the effective environment. In Mode 2, previously dominant variants may suddenly be less adapted than their competitors to new conditions, thus losing their selective advantage over and being eclipsed by formerly less well-adapted forms.

Pursuing the question of change in the archaeological record from the perspective of evolutionary human paleoecology, archaeologists are capable of identifying which of these modes of change occurs in specific instances and of demonstrating the causes of each change. I shall show how this might be accomplished by applying the ideas of evolutionary human paleoecology to investigate a problem that has long been of interest to scholars of many disciplines: the relationship between human adaptation and climatic change.

Depending as we do on temperatures and moisture favorable to our economic and physical well-being, scientists of many kinds have become concerned with the impact of climatic fluctuations on the human condition. Climatologists (Bryson and Murray, 1977; Lamb, 1977), historians (Ladurie, 1971) economic historians (Jones, 1964; Pfister, 1978; Post 1974), demographers (Utterstroem, 1955), archaeologists (e.g., Baumhoff and Heizer, 1965; Baerreis et al.,

1976; Fitting, 1978; Fitzhugh, 1972, 1975; Frison, 1975; Griffin, 1960a, b; Henry et al., 1981; Reher, 1977; Winter, 1976) and others (e.g., Journal of Interdisciplinary History 10[4]) take an active interest in the topic from a multitude of perspectives. In archaeology, there are two common approaches to explaining relationships between climatic change and changes in the archaeological record: Deterministic and Ecological.

Determinists conceive of subsistence as largely responsible for the structure and complexity of culture (the concept of culture core, Steward, 1955) and, since subsistence activity is the point of articulation between people and their environments, assume that some cause and effect relationship exists between the environment and most aspects of culture (Meggers, 1954). Because human behavior is thus seen as a dependent variable responding to environmental conditions, and because climate is conceived of as the independent variable conditioning environmental change (e.g., Cleland, 1966; Raab, 1977; Watson et al., 1971), an observed correlation between climatic and cultural changes is accepted as prima facie evidence that climate has caused culture to change (Baumhoff and Heizer, 1965; Fitting, 1978; Gunn and Adams, 1981). Thus, when climatic and cultural events coincide, change is assumed to occur through Mode 1, as described above.

Adherents to the alternative, ecological approach criticize determinists for drawing hasty conclusions based on the unexamined implications of abbreviated cause and effect chains (Dincauze, 1981; cf. Baerreis et al., 1976; Chatters, 1976a; Jochim, 1979a; Snow, 1981). Denying that coincidence between cultural and climatic events is adequate evidence of a causal relationship, they argue correctly that linkages between human behavior and climate must be fully investigated by analyzing the impact of climate on people's biotic resources (Baerreis et al., 1976; Binford, 1968b; Chatters, 1976a; Dincauze, 1981; Streuver, 1968a, 1971; see all Pfister, 1978). They thus recognize the importance to evolutionary analyses of identifying change in the niche and effective environment (e.g.,

Binford, 1968b). In addition, whereas determinists attempt to explain any change as a function of climate, from the content and distribution of adaptive patterns (e.g., Baumhoff and Heizer, 1965; Fitzhugh, 1972; Griffin, 1960b; Irwin-Williams and Haynes, 1970) to monument construction (Griffin, 1960a; Gunn and Adams, 1981), house form (Dekin, 1972; O'Connell, 1975), and projectile point style (Bedwell, 1973; Swanson, 1972), this second approach concentrates primarily on adaptive patterns (e.g., Buchner, 1980; Butzer, 1981; Klein, 1977; Reher, 1977; Streuver, 1968a; Winter, 1976).

Of these approaches, the ecological program is more appropriate to an archaeology conceived as evolutionary human paleoecology, and the ideas of many of its proponents (Binford, 1964, 1968b and Streuver, 1968a) have contributed to the method I now offer.

The Method

My contribution to the issue of interaction between human behavior and climatic change is a systematic, decision-making model (Figure 1) that ascertains first, whether any evolutionary change has occurred, determines whether that change is of the Mode 1 or Mode 2 type, and if Mode 2, investigates the role of climate in precipitating the changes in selection pressure that alter the fitness of variant forms of adaptation. In doing so, it asks a series of questions of separate bodies of data on adaptive pattern, resource use (niche), effective environment and the biophysical environment as a whole. Answers to these questions determine the form of further analyses and provide solutions to the question of cause for change in the archaeological record. Solutions are actually six alternative hypotheses that the method is designed to test.

Hypothesis I. The change is not directly related to adaptation selection and, therefore, the environment are not involved.

Hypothesis II. The change fits the pattern expected if natural selection were operative and is of the Mode 1 type, with selective pressures changing through the generations of new behavioral variants.

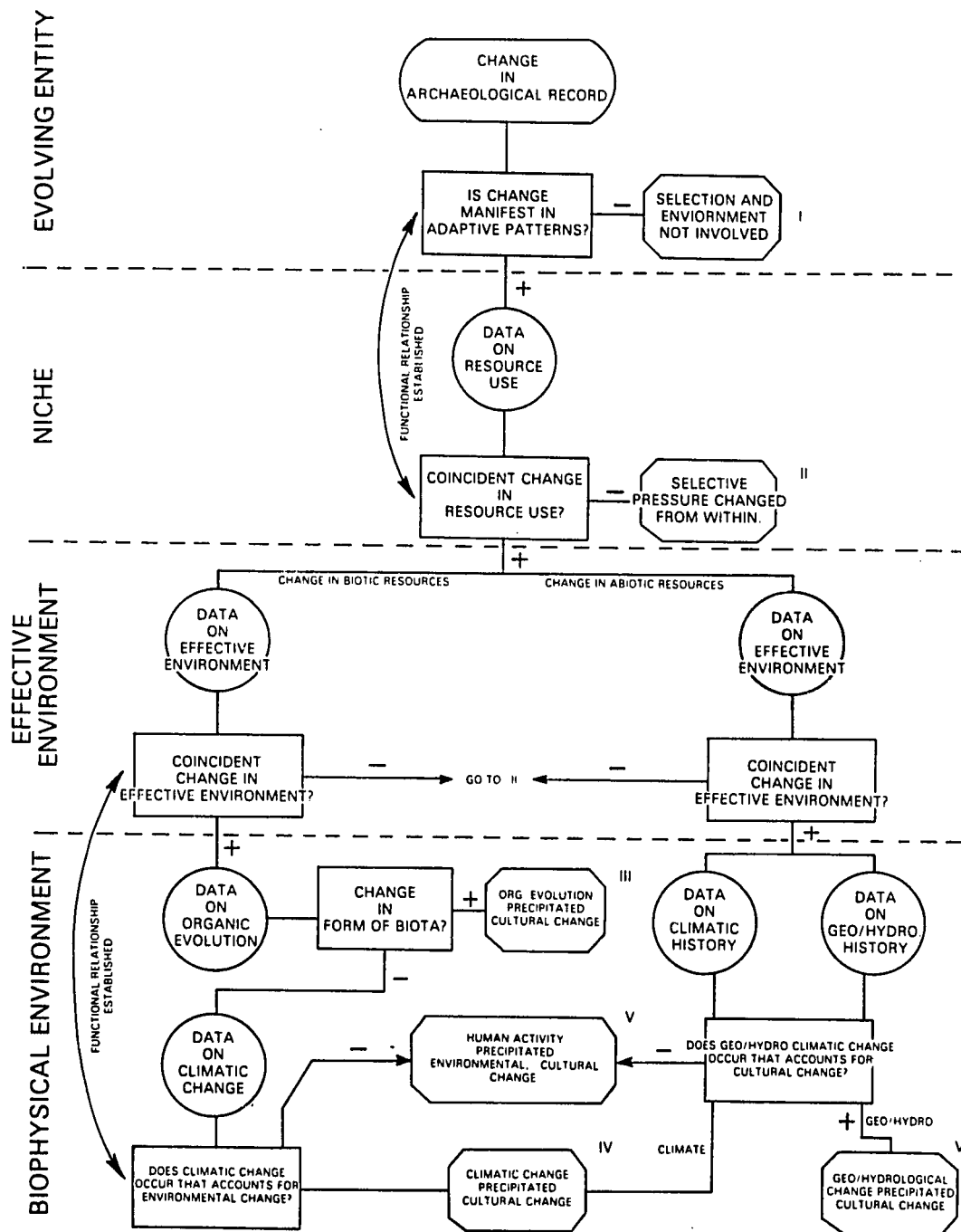


Figure 1. Flow chart model of a method for investigating the evolutionary process and identifying the relationship between change in the archaeological record and environmental events. Rectangles denote questions; circles, data input; octagons, hypotheses.

Hypothesis III through VI all conclude that natural selection can account for the observed change, but differ from Hypothesis III in their assertion that change is of the Mode 2 type; a changed environment has altered the selective pressures acting on already coexisting behavioral variants. Variable components of each hypothesis are these:

Hypothesis III. The change in environment and, there, selective pressure resulted from evolution within prey species populations.

Hypothesis IV. The change in environment and, therefore, selective pressure was precipitated by climatic events.

Hypothesis V. The environmental change effecting altered selective pressures was caused by human activity.

Hypothesis VI. Altered selective pressures result from a change in the geological or hydrological environment.

For descriptive purposes, the method is divided into four segments according to the three components of an evolutionary event, Evolving Entity, Niche, and Effective Environment, plus the Biophysical Environment that may alter the content of the Effective Environment. In the sections that follow, I discuss each segment of the model, defining necessary concepts and specifying the source and quality of data required to answer the questions posed in that segment and thereby achieve adequate tests of competing hypotheses. Before doing so, however, I must deal with a basic issue, the concept of artifact, which is important to the testing of alternative hypotheses and therefore critical to the method's successful application.

Artifact. The term "artifact" is usually reserved for the portable, discrete objects we recognize as made by people (e.g., Sharer and Ashmore, 1979) but is more broadly defined as "any phenomenon whose properties are the result of human activity" (Dancey, 1981:12; cf. Dunnell, 1971a). This second definition is complete and exhaustive, but it presumes a prior stipulation of those characteristics that distinguish those properties that result

from human activity from those properties that do not. In fact, archaeologists identify the entailments of human activity in much the same way paleontologists recognize some characteristics of sedimentary rocks as the remains of living things: by the process of elimination (Kitts, 1974). Those characteristics of a phenomenon that we cannot account for as products of natural biophysical processes (excluding people from the biota for a moment) we assume to result from the activities of the only remaining agent: Homo sapiens.

If something can be accounted for by natural processes, we cannot distinguish it from other components of the environment and cannot identify it as an artifact, even though people might have created it. For example, complete unmarked animal bones found in a cave that might have been used as a den by some carnivore are not necessarily artifacts, even though large quantities of stone tools and other debris suggest intensive human use of the site. Conversely, animal bones with deep, narrow, parallel incisions that cannot be attributed to gnawing by a rodent or predator can be identified as artifacts by virtue of the non-natural incisions. Objects in unusual spatial context are artifacts, as well. Thus, an artifact is any phenomenon whose properties cannot be attributed to natural (non-human) processes (Chatters, 1976b). This includes discrete artifacts, features and many of the things Binford (1964) calls ecofacts.

Larger scale phenomena can also be artifacts under this definition. In England, for example, many changes in the content and distribution of floras and insect faunas of the late Holocene cannot be explained climatically or by any other event, and thus are perceived as consequences of Neolithic and Iron Age agricultural practises (e.g., Sprall and Simmons, 1976). These new plant communities are artifacts. Therefore, in evaluating alternative hypotheses regarding causes for change in resource use and effective environment, new adaptive patterns or different forms of environment can be identified as artifacts and thus attributed to human activity

only when biotic, geologic, hydrologic and climatic causes have been ruled out.

Artifact is my primary concept and, because artifacts and their positions - the archaeological record - are the subject matter of evolutionary human paleoecology, artifact is the basic concept of the entire discipline.

Evolving Entity

We begin the method with an observation of change in the archaeological record, then proceed to test a first set of hypotheses. The change is either the result of natural selection and therefore may be related to environmental and climatic events, or selection and therefore the environment is not involved in any causative way. Because only adaptive behaviors are visible to natural selection, what we are asking here is whether the change in human activity that we read in the artifacts is adaptive or non-adaptive in nature. That portion of the archaeological record that is the consequence of adaptive behavior is the environmental distribution of functional classes of artifacts at any scale - adaptive patterns. Thus, the first two hypotheses are tested by answering the question: is the change manifest in adaptive pattern? If the change is evident in a shift in the archaeological fitness of alternative adaptive patterns or their components, the event is evolutionary and we proceed. If the answer is negative, the change cannot be the result of natural selection; Hypothesis I is the best answer and this analysis ends.

It is at this initial point that the deterministic approach to climate-culture relationships first fails: culture is perceived as closely dependent on environment and adaptive significance is at least implicitly ascribed to all aspects of human activity.

Griffin's (1960a) attempt to explain decline of the Hopewell mortuary complex in environmental terms is an example. Assuming Hopewell to have been dependent on maize agriculture, he suggested that climatic deterioration weakened this subsistence base and thus

led to the demise of mortuary ritual. Notwithstanding the now-accepted non-maize subsistence of Hopewell (Asch et al., 1979; Bender et al., 1981; Streuver and Vickery, 1973), for Griffin's hypothesis to be testable, he would first have to demonstrate some functional relationship between mortuary behavior and maize subsistence, i.e., that grave mounds and complex earthworks were components of adaptive patterning. This he has not done. The same problem attends the efforts of Gunn and Adams (1981) to account climatically for variations in activity at nine urban centers in Mesoamerica and by others to explain change in house and projectile point form (e.g., Bedwell, 1973; Dekin, 1972; O'Connell, 1975; Swanson, 1972). In fact in O'Connell's (1975) case, settlement and land use patterns seem to have remained constant while house form changed from large semi-subterranean to small surface forms.

No change can be attributed to climate unless its relationship to adaptation and thus to the selective process is first confirmed.

Niche

Having obtained a positive answer to the question of change in adaptive patterns, we now proceed into the Niche segment of the model. As noted earlier, niche is the sum of all interactions between an organism and its environment, and can be thought of as an N-dimensional hyper-volume (Hutchinson, 1957, 1965) from which we isolate three primary dimensions: space (habitat), time and resources (Pianka, 1974; cf. Christensen and Fenchel, 1977). Human habitats are observed archaeologically as the environments in which artifacts occur, and are thus an aspect of the environmental distributions comprising adaptive patterns. Therefore, as we observe changes in the spatial component of adaptive patterning, we are also observing variation in the space dimension of the human niche. Consequently, we cannot consider space niche as a separate phenomenon, for that would entail answering two questions with the same data set, inappropriate redundancy in an analysis designed to ascertain causes for change in adaptive pattern by studying the ecological

niche in relation to such changes. What remain to be investigated in this segment of the model are the time and resource dimensions of the niche.

These two dimensions are subsumed here under the topic of resource utilization, which includes both the kinds and proportions of resource types and the scheduling of resource exploitation activity. The intent of this segment is to determine whether change in the archaeological record, which has already been identified as attributable to natural selection takes the Mode 1 form or whether it might perhaps be Mode 2 and thus could involve climate. To provide an answer we acquire data on resource utilization and ask "Has coincident change in resource use occurred along with the change in adaptive pattern?" If not, there can be no relationship between the archaeological change and effective environments, since that relationship is mitigated through the niche. Changes in selection pressure that occasioned the shift in adaptive pattern therefore are most likely to have arisen through generation of new variants of behavior that were better adapted than their predecessors. They may, for example, entail some societal or demographic restructuring that alters adaptive pattern and habitat without affecting other niche dimensions. With a positive answer, we may proceed with the method, providing one additional condition is met.

Like archaeological change and climate in general, a coincidence between changes in niche and adaptive pattern does not constitute prima facie evidence of a relationship between them. Therefore it is necessary to demonstrate a functional relationship between these phenomena. Such an argument should be firmly based on ecological principles and an understanding of prey behavior (where resources are living things). One of the more promising approaches to this problem is optimal foraging theory (cf. MacArthur and Pianka, 1966; Orrians and Pearson, 1979) which follows from the assumption that organisms minimize feeding time and maximize net caloric intake by concentrating on food items that yield the highest return per unit time expended. To employ such models, archaeologists

can first measure the resources used by former peoples, note the spatial distribution of artifacts and settlements and assess whether those distributions conform to the predicted optimal locations for acquiring the resources known to have been utilized. For example, given changes in adaptive pattern and resource use between Time 1 and Time 2, if the adaptive patterns in Time 1 conform to those expected from an ecological analysis of resources, and the same is true of Time 2 then the changes are functionally related and a proximate cause for the archaeological change is alteration in the ecological niche. This approach is of course less robust when considering older time periods, during which environments and constituent species may have been different from any we observe today. Optimal foraging theory has often been used to predict site location (cf. Perlman, 1980) and for various other purposes (e.g., Croes and Hackenberger, 1981; Hackenberger, n.d.; Jochim, 1976, 1979b; Styles, 1981).

Less sophisticated, but nonetheless convincing arguments can also be made from an anthropological point of view using ethnographic data to generate models of niche-adaptation relationships. Reher's (1977; Reher and Frison, 1980) study of adaptive process on the shortgrass plains is an excellent illustration. Arguing from ethnographic data that mass kills of bison were necessarily a group activity, he suggests a mechanistic relationship between intensified bison jumping activity and increased aggregation of human populations on the Northwestern Plains during the late prehistoric period. His suggestion attains credibility through his observation of stylistic diversity in the projectile points found in bone beds attributable to single kill episodes (Reher and Frison, 1980). Taking this variation as an indicator of ethnicity he concludes that aggregation of otherwise distinct groups was indeed a necessary component of the mass kill.

If such a functional relationship between adaptive pattern and niche is established, we proceed to the next segment of the model. If not, our analysis is stymied until more niche data can be found

or a better understanding of niche-adaptive pattern relationships is achieved.

Measuring Resource Utilization. Resource use has two components; scheduling and the kinds and quantities of resources themselves. Measurement of resource scheduling is the pervue of seasonality studies, which have recently been summarized in detail by Monks (1981). Measurement of the resource niche itself is a more important problem and I shall discuss it at some length, beginning with a definition of resource that is appropriate to archaeological problems, then considering how resources and resource change are identified and quantified.

Conceivably, plants, animals, rocks, minerals and other phenomena comprising the resource niche of a human population might be identified as any of the stuff normally occurring in the natural environment that is found in an archaeological context. This is the ecofact concept of Binford (1964), who subsumes under this term not only those objects recovered from an archaeological site but also those species and materials found in the site's immediate proximity (e.g., Raab, 1977; Roper, 1979; Streuver, 1968a). However, the mere association between components of the environment and defined evidence of human activity (tools, features, facilities) does not a priori identify those components as having been utilized by people. The coincidence of modern plant and animal communities with archaeological sites may not reflect former relationships between people and biota (King, 1978) and are no proof of human resource exploitation (Madsen, 1981). Plant fragments, animal bones and even flake-like pieces of lithic material can be deposited in archaeological situations by non-human means (Dancey, 1981; Hevly, 1981; Minnis, 1981; Thomas, 1981) and, despite efforts to the contrary, (Thomas, 1971a), the only means for distinguishing between people-deposited and naturally deposited stuff is an arbitrary one, the concept artifact (Chatters, 1976b; cf. Minnis, 1981; Rhode, 1981). Components of the resource niche are, therefore, defined for

archaeological purposes as those parts of the natural environment that occur as artifacts. There are two exceptions here: water and protection from the elements, neither of which leaves tangible remains, but both of which are essential to human survival. These resources must be inferred by spatial association and, in the case of water, the presence of resource-specific facilities such as irrigation ditches and reservoirs.

Some controversy exists over the proper approach to identifying the resource niche (Jochim, 1979a), with two somewhat well defined camps. One maintains that direct evidence in the form of remains found in archaeological sites is the only certain indicator of resource exploitation; the other believes in allowing indirect evidence, such as spatial association.

There are many direct means available for niche identification, including zooarchaeology (Chaplin, 1971; Daly, 1969; Gilbert, 1973; Uerpmann, 1973), paleoethnobotany and palynology, (Ford, 1979; Hevly, 1981; Renfrew, 1973), coprolite analysis, (Callen and Cameron, 1960; Heizer and Napton, 1969), isotopic and chemical analyses of human bone (Price and Kavanagh, 1982; Van der Merwe and Vogel, 1978; Vogel and Van der Merwe, 1977) and geologic and metallurgical studies of abiotic raw materials. Discussion of each is well beyond the scope of this discourse.

Indirect approaches usually rely on ethnographic analogy or some sort of optimal foraging model to assume that if site locations coincide with the modern or reconstructed distributions of those plants, animals or abiotic materials we think people were utilizing or believe they should have utilized if optimizing, then those species or materials comprised the resource niche of site inhabitants (e.g., Bettinger, 1977, 1981; Raab, 1977; Ranere, 1970; Thomas, 1971b, 1973; Williams et al., 1973; cf. Beckerman, 1980; Binford, 1964; Roper, 1979). Another form of indirect analysis presumes the niche by reconstructing tool and facility functions through analogy (Bettinger, 1977, 1979; cf. De Boer, 1975). Yet another infers the niche from preconceptions about the kind of

subsistence base people require to achieve a certain level of cultural complexity (e.g., Griffin, 1960a).

In various papers, Madsen (1981; Madsen and Berry, 1975) criticises indirect approaches, arguing that relationships between a site and the components of its environment may have been different in the past and that ethnographic analogy is inadequate evidence for resource utilization (De Boer, 1975). He maintains that the only evidence usable for analyses beyond the stage of resource utilization is direct evidence; the discovery of those resources in the archaeological context. Thomas (1981) counters Madsen's argument with a caveat of his own, pointing out that not all floral and faunal remains found in sites are necessarily used by people and that many may arrive naturally. This does not negate Madsen's argument, but only supports my stipulation that resources be identifiable as artifacts.

For effective use of this model, resource data should come from direct evidence. If indirect means of resource identification are used, the inferential data that results (based as it is on an assumption that association equals use) reduces the parsimony of the analysis and diminishes the robustness of any conclusions. This is not to categorically rule out the use of indirect measures, since in many environments, actual resource data may rarely be found, but simply to point out that only direct evidence is fully adequate to the needs of the method advocated.

Resource quantification. Several authors have suggested that archaeologists incorporate concepts of niche breadth into their ecological models (Christenson, 1980; Kirch, 1980; Hardesty, 1980). However, calculations of niche breath require precise measurement of niche variables and knowledge of the full spectrum of resources utilized by an organism (Levins, 1968; Pianka, 1974). Archaeology lacks the ability for quantification at that level. Many factors mitigate against it and can be subsumed under two categories: recovery biases and counting methods.

In zooarchaeological and paleoethnobotanical analyses, what you see is not necessarily what the people got. Variations in the pre-depositional treatment of different kinds of plants and animals (Binford and Bertram, 1977; Ducos, 1975; Gasser and Adams, 1981; Ford, 1979; Minnis, 1981; Noe Nygaard, 1977), differential preservability of various types of plant parts and animal bone (Binford and Bertram, 1977; Casteel, 1971; Hevly, 1981; Munson et al., 1971; Minnis, 1981) and differential retention due to recovery techniques (Casteel, 1972; Ford, 1979; Payne, 1975), all contribute to weaken the relationship between the kinds and amounts of species utilized and those we actually count. Under ordinary circumstances, seeds, charred plants of all types, and larger, denser bones comprise the remains of biotic resources in archaeological sites. Compounding these biases are problems with quantification and the assignment of relative importance to the various resources we are fortunate enough to discover. The relationship of measures of faunal abundance to the number of animals actually used is uncertain (Grayson, 1973, 1978, 1979a) and although the quantification problems of paleoethnobotany have received less attention, they are at least equally severe. Therefore, the kinds, amounts and even relative proportions of various species used by people at any one time are for all practical purposes forever out of our reach.

If we cannot precisely quantify the resource niche, what then can we do? The answer is: think in relative terms, in terms of change in the importance of various resources. Since it is change, not the absolute relationship between resource variables that concerns the method I present here, only change in resource utilization is important. In considering change, however, we are beset by the difficulty of intersite comparison (Lawrence, 1973) and must, therefore, assure that factors affecting preservation between sites are equivalent or at least devise means to control for the differences.

Niche: Summary. This segment of the model addresses the question of whether there is a change in time and/or resource dimension

of the ecological niche. I have defined components of the resource niche for archaeological purposes, suggested that direct evidence, rather than inferential data should be employed in this context, and pointed out that the archaeological record only allows us to consider change in the relative importance of resources, not their levels of absolute significance. If change in resource utilization coincides with and can be functionally related to a shift in adaptive patterns, we proceed with the method.

At this point, the model (Figure 1) divides into two parts, depending on whether niche change is manifest in biotic or abiotic resources. The analytical procedures are the same in each half and the kinds of questions asked are equivalent, but the procedure splits here because the environment causes for and thus the role of climate in precipitating changes in selective pressure are different. I shall follow the left side of Figure 1, and discuss how one might determine the cause of archaeological change if the niche changes are biotic, commenting only occasionally on use of the right abiotic side.

Effective Environment

Regardless of which path is taken from the question of niche change, we now consider the part played by the effective environment. Effective environment is defined as those parts of the total environment with which an organism is in regular or cyclical interaction (Allee et al., 1949). Because we identify environmental interaction through the niche, the effective environment is those parts of the biophysical environment, i.e., plants, animals, that also comprise the organism's ecological niche. Changes in the seasonal or geographic distribution or relative abundances among variables of the effective environment affect the ability of the subject organism, people, to acquire the resources to which they are adapted, exerting selective pressure on patterns of adaptation. For example, given adaptive pattern variants A1 and A2 and their niches, we are considering distinct forms of effective environment, E1 and

E2. At Time 1 the organisms comprising E1 are more available than those of E2, hence pattern A1 is selected for over A2 and will have higher fitness. Then, in Time 2, the biota changes and E1 becomes less available than E2, altering selective pressures on adaptive variants and enhancing fitness of pattern A2. This of course is change of the Mode 2 kind.

Thus, what we are asking in this segment of the model is: Has there been a change in effective environment that is coincident with niche change and is therefore the selective force behind changes in adaptive pattern? If not, then the impetus for change originates in the advent of new, better-adapted cultural variants and change is of Mode 2; Hypothesis II is again correct. If the answer is positive, proceed to investigate the cause of change in the effective environment.

Three issues are important at this juncture: (1) the portion of the effective environment that we study, (2) the timing of changes in effective environment relative to niche and adaptive pattern change, and (3) measurement and sources of data.

Portion of the Effective Environment. In our analysis of ecological niche we may observe that when change occurs, some niche components remain stable while others shift in frequency, becoming more common, less common or disappearing entirely. It is through those changing components - the species of plants and animals whose use changes over time - that selection pressure is being manifest. Therefore, in observing temporal behavior of the effective environment, the only portions of biotic assemblages we are concerned with are the species whose contribution to the ecological niche also changes. For example, if bison, yampa root, huckleberries and deer comprise the biotic resource niche, and only the proportions of bison and deer vary in coincidence with adaptive patterns, then it is the relative environmental availabilities of these animals alone that are of interest.

Effective environment thus bears a restrictive meaning in the context of Figure 1.

Timing of changes in effective environment. If environment is to be identified as the variable precipitating adaptive pattern change, the former event must precede the latter (Baerreis et al., 1976; Dincauze, 1981). Were the reverse to be true, environmental change certainly could not be identified as the source of selective pressures effecting changes in archaeological fitness. However, if an environmental event precedes some shift in adaptive pattern fitness by too long a time (more than a century or two) and there is no evidence at that time for the existence of the adaptive pattern variant that has more or less quickly replaced its predecessor, we cannot identify environment as the catalyst for change. This latter situation is complex. The environmental conditions which develop before the new adaptive variant appears may in fact be the conditions that give it selective advantage over its predecessor. Both events, environmental and cultural are, thus, part of the cause for change. However, environmental and cultural variables (selective pressure and the variant forms of behavior it acts upon) are always part of the natural selection equation. What we are concerned with here is whether or not the event that precipitates a change in selection pressure is environmental or cultural. If environmental change precedes the development of new behavioral variants, the cultural event (generating a new form of behavior) is the catalyst for change, and change is the Mode 1 type.

Therefore, the question asks whether or not the environmental and adaptive pattern changes are coincident. In archaeological time, if the changes in biota and archaeological record appear to coincide or the biotic change is just precedent, then we may identify the biotic change as the phenomenon precipitating the evolutionary event. I am intentionally vague here. "Just precedent" subsumes a variable quantity of time, depending on the precision of archaeological and paleoecological chronologies.

Measurement and sources of data. Various paleoecological methods are available for investigating the composition of former plant and animal communities, including palynology (Faegri and

Iversen, 1975; Moore and Webb, 1978), plant macrofossil analysis (e.g., Harper and Alder, 1970; 1972), analysis of plant phytoliths (Lewis, 1981), and paleontology (e.g., Freeman, 1973; Guthrie, 1968a, b; Voorhies, 1969, 1981). However, numerous biases constrain the application of these methods and thus limit our ability to measure biotic populations (e.g., Grayson, 1981; Moore and Webb, 1978), restricting us, again, to the mere observation of change in proportionate abundance of species. Nonetheless, since change is all we wish to measure here, these limitations do not compromise the method's utility. Paleontological and palynological methods are discussed in Chapters 9 and 10.

Contrary to the suggestions and practice of some scholars (e.g., Cleland, 1966; Dincause, 1981; Freeman, 1973; Harper and Alder, 1970, 1972; Henry et al., 1981; McMillan, 1976; Strauss et al., 1980), history of the effective environment should not be read from the same data as the ecological niche (cf. King and Graham, 1981; Rice, 1975). The reasons are straightforward. First, plant and animal remains found in archaeological contexts, especially those we are able to identify as components of the ecological niche, are not simply "elements of a former natural environment" (Cleland, 1966:13). People are responsible for their presence and taxonomic composition, and we know from extensive studies of contemporary populations that people tend to be selective foragers. Consequently, changes in composition of the ecological niche are not necessarily a reflection of biotic community composition, but may simply denote changing strategies of resource acquisition. If we deny this fact, the effective environment step in my method is irrelevant and we ought simply to proceed to the Biophysical Environment.

In fact, there are some cases where the effective environment segment of the method must be skipped; when niche change involves domestic plants and/or animals. Because these creatures may not occur in non-archaeological contexts, either due to low pollen production or protection from agents that normally create

paleontological deposits, their presence as artifacts may be the only evidence we have of their existence.

Second, to identify niche and effective environment from the same data is to conflate cause with consequence (cf. King and Graham, 1981). How are we to find any difference between niche history and environmental history if both sets of information come from the same data?

Paleoecological data that is to inform about changes in effective environments must come from non-archaeological contexts if possible. One might counter that remains other than the niche constituents might provide information on past environments by enabling reconstruction of climate and thence, through knowledge about plant and animal ecology, provide the needed environmental data. Indeed they might, except they would again circumvent the method and deny the possibility of Hypotheses II, III, V and VI.

In the Effective Environment segment we acquire paleoecological data on biota comprising the changed portion of the ecological niche from non-archaeological sources and, if a coincident (in archaeological time) change is observed between effective environment and adaptive pattern changes, we proceed to the next segment of the model.

Biophysical Environment

Having established that selective pressures were exerted by a change in the biological environment (or physical in the case of the right diagram, Figure 1), we may wish to continue and learn what independent variable, climate, organic evolution or human activity precipitated the evolutionary event. At this level, we face three alternative hypotheses: III. Organic evolution has reorganized the productivity or accessibility of the biota, leading to change in effective environment and thus precipitating a shift in human adaptation, IV. Climatic change altered the composition of the biotic environment, thus leading to the change in adaptive pattern fitness, or V. Human activity wrought an environmental change and

precipitated the evolutionary event. In the physical environment half of the diagram, we also test three hypotheses with climate, human activity and geological or hydrological change as the potential catalysts. I discuss the thought behind each hypothesis and the data required for its testing in subsequent sections.

Hypothesis III: Organic evolution. If the form of one or more living members of an ecosystem changes through the evolutionary process, chances are the creature's place in the ecosystem - its niche - changes as well. Should that occur, the creature's abundance and availability to people may also change. Therefore, if the components of the human resource niche change organically, at the same time or just prior to an observed change in human adaptive patterns, this organic change is the event most likely to have precipitated the change in effective environment and thus, the change in human adaptation. We might argue, correctly, that the organic event might not have affected the species' niche, and that climate or human activity actually brought about a change in selective pressures. However, without applying an evolutionary study of the kind in Figure 1 to the organism itself, we cannot demonstrate the truth of our assertion.

Organic change is perceptible in the paleontological record of faunal and floral macrofossils and no constraints need to be placed on the source of such data. Even the same data we use to discern people's resource niche is appropriate, since our concern here is only with form, not quantitative relationships. Among the most familiar and oft-studied manifestations of organic change are domestic grasses, in which increased kernel size and number (Helbaeck, 1966; Mangelsdorf, 1974) and rachis strength (Zohary, 1969) affected plant productivity and harvestability. The remains of these plants are almost all from archaeological contexts.

When no organic evolution is evident, proceed to analyze climatic data and test Hypotheses V and VI.

Hypothesis IV: Climatic change. If climatic changes are coincident with or just precede the observed environmental events, and if a functional relationship can be established between them in ecological terms, then climate is the catalyst for people's adaptive shift.

Functional relationships are established by obtaining knowledge of the ecology or in the case of extinct animals, the inferred ecology of plants or animals in the human niche, and ascertaining their probable response to climatic fluctuations. If observed changes in climate correspond to those predicted from ecological data, then climatic and biotic changes are causally related (e.g., Buchner, 1980; Reher, 1977; cf. Fitzhugh, 1972).

When people's effective environment consists of terrestrial fauna, an additional step (not shown in Figure 1) is necessary. Animals' effective environments should be investigated for coincident and therefore causative change and if any is observed, organic evolution, then climate may be tested as possible causes. Where proportions of flora or fauna comprising the animals' effective environments do not also change, then the original faunal shift is an artifact and Hypothesis V is the best alternative.

Climatic reconstructions are available through numerous geologic, isotopic and paleontological means, and many of these are discussed in Chapter 11 (see Lamb, 1977, for a survey of methods). What concerns us here is the source and therefore the quality of resultant climatic histories. I impose three constraints. Climatic data should (1) not be derived from the same data used to reconstruct effective environments and human niche, (2) whenever possible come from non-archaeological contexts, and (3) be relevant to local conditions and not merely be derived from worldwide reconstructions.

The first constraint is redundant with one imposed on effective environments. When climate and biotic environment are read from the same data set, cause and effect are confused, with no new knowledge and a potentially spurious reconstruction of climate being the result. However, if counts of plants and animals not included in

the effective environment are acquired from the same site, these might be used as climatic indicators without serious consequences.

However, this cannot be done with confidence in an archaeological context, unless one can demonstrate convincingly that the phenomena from which climate is inferred are independent of human intervention (sedimentary deposits, for example). Because we have found artifacts we know people are responsible for part of the site's contents, but how much? Non-artifactual plant, animal and mineral remains might all be present because of natural processes, but they also might not. Our artifact definition distinguishes human from non-human origin to allow us to systematic means of identifying those phenomena for which people are most likely responsible. Many other objects in a site may also be anthropogenic, but we cannot know which. Therefore, since we cannot assume that people gathered plants and animals randomly from their surroundings, we cannot be certain the site's contents accurately reflect the environment at large (cf. Rice, 1975).

Climatic reconstruction from pollen, fauna and other archaeological materials are commonplace today, a part of the growing interdisciplinary character of research (Dincauze, 1981; Schoenwetter, 1981; e.g., McMillan, 1976; Straus et al., 1980; Grayson, 1977; Harper and Alder, 1970, 1972). This may be necessary where no alternative source of data is available, but the results ought to be applied with caution and checked against regional climatic histories to detect unacceptable deviation from expected patterns (e.g., Henry et al., 1981; McMillan and Klippel, 1981). Others are now recognizing the greater robustness of reconstructions based on non-archaeological remains and are designing their research accordingly (e.g., Brown et al., n.d.; Anderson and Semken, 1980).

When not derived from archaeological strata, paleoclimatic information of local origin is preferable to reliance on regional or worldwide syntheses. Correlation of universal climatic schemes, such as the Blytt-Sernander sequence originally developed in Scandinavia, to events in North and Central America (Baerreis and

Bryson, 1965a, b; Dekin, 1972; Fitting, 1978; Griffin, 1960a, b; Gunn and Adams, 1981; Wendland and Bryson, 1965a, b) is criticized by Snow (1981), and Bryan and Gruhn (1964) decry the unquestioning application of Antev's tripartite sequence of Holocene climates (e.g., Baumhoff and Heizer, 1965). Although there is growing evidence that atmospheric temperature fluctuates on a worldwide scale in response to variations in solar output (Denton and Karlen, 1973; Lamb, 1977), the impact of these general trends on local climates are often distinct, even opposite in sign (Bryan and Gruhn, 1964). After all, it is to local environments, not worldwide trends that people become adapted.

When climatic and biotic changes are not coincident, Hypothesis IV is disproven, leaving Hypothesis V as the best alternative.

Hypothesis V: Human activity. By the process of elimination we have ruled out non-human causes for environmental change and are left with the conclusion that human activity changed the effective environment, which in turn exerted selective pressure on variant forms of adaptive pattern; thus occasioning a change in the archaeological record.

Hypothesis VI: Geological or hydrological change. Tectonic or volcanic activity and changes in the structure and distribution of river systems comprise the geologic/hydrologic category of change. Their impact on the availability of abiotic resources, such as stone (e.g., obsidians), minerals, soil and water could conceivably precipitate changes in adaptive pattern. If this alternative and climatic change both fail to account for variation in the effective abiotic environment, Hypothesis V is again the best answer.

Application: The Pahsimeroi Valley Study

I have now presented a method for investigating the process of change in patterns of human adaptation, based on the concepts of

evolutionary human paleoecology, that employs archaeological, paleoecological, paleoclimatic and geologic data to determine the mode of change and test six alternative hypotheses for cause. In the nine chapters that follow, the method is applied to the archaeological record of the Pahsimeroi Valley, in the high, cold steppes of the Central Rocky Mountains. Chapter 3 describes the Project Area and details the reasons for its choice. Adaptive patterns, specifically settlement and land use patterns, are the subject matter of Chapters 4 through 7; 4 presents techniques for data recovery, 5 and 6 - functional and chronological analysis and classification of artifacts, and 7 compiles these analyses in a synopsis of adaptive pattern change from 8000 BP to the present. Two of these changes are then isolated and the causes of their occurrence investigated by the procedure just described. Chapter 8 identifies ecological niches before and after adaptive pattern changes, Chapter 9 and 10 look at the history of effective environment and 11 considers the role of climate.

CHAPTER THREE

Project Area: The Upper Pahsimeroi Valley

The relationship between human adaptation and climatic change can be established using the method outlined in Chapter 2, but that approach requires a large amount of data of high quality for its successful application. Information on human adaptive pattern and niche, and biotic, geologic and climatic histories must all be available if the method is to lead an investigator to the best hypothesis accounting for any instance of change in human adaptation. Wherever possible, each data set should be acquired from a source independent of all other data sets.

Because of these requirements, the region in which the method is to be employed must contain the following: (1) an archaeological record from which adaptive patterns can be readily discerned, preferably with artifacts visible on the land surface, or an already established chronology of human adaptation, (2) archaeological sites in which remains of biotic resources (floral and faunal remains) are preserved, or a record of such information from previously excavated sites, (3) potential sources of paleoenvironmental data, including paleobotanical sites like lakes, springs or bogs, geological settings where nonarchaeological assemblages of bones contemporary with the archaeological record may exist, and features from which the area's geologic history can be discerned, and (4) potential sources of information on paleoclimates. In the case of requirements 3 and 4, previously completed paleoenvironmental and paleoclimatic reconstructions would be advantageous.

My purpose here is to demonstrate the method's effectiveness, so two other criteria were important to the choice of a project area. First the area should be one where changes in paleoclimate and human adaptation had occurred, so that I might have episodes of significant change as objects of study. Second, an ecologically

sensitive area, such as a desert or arctic region, in which minor changes in precipitation and temperature might have marked effects on flora, fauna and/or hydrology, was preferable over a more mesic and/or tropical environment with a broad range of tolerance for small scale climatic variation. Episodes of climatic change sufficient to exert selective force on human adaptations may occur more frequently in ecologically sensitive regions, providing more events of climatic and, potentially, of cultural change and thus an optimal test case for the method.

At the outset of this study, I surmised that the Pahsimeroi Valley of East Central Idaho met these requirements and preliminary investigations in 1973 and 1974 (Chatters, 1976c) confirmed the area's suitability. Previous archaeological and paleoecological research at nearby sites indicated frequent episodes of change and artifacts spanning the entire period of human occupancy were present on the ground surface. Buried archaeological sites with faunal remains and, potentially, carbonized plant fragments were present, though not common. Potential sources of paleoecological and paleoclimatic data existed in the form of lakes for pollen, nonarchaeological accumulations of bone, and ancient trees. Finally, the area appeared to have been geologically stable during the Holocene (except for small moraines developed above 3000 m), thus reducing one potential source of environmental variability to a constant. In the sections to follow, I briefly describe the Pahsimeroi Valley, pointing out those characteristics that make it a suitable region for the study. I then define the actual Project Area, the portion of the valley in which investigations were conducted.

The Pahsimeroi Valley

Physiography and Geology

Three parallel mountain ranges rise abruptly from the Snake River Plain in East Central Idaho, trending northwestward to the rugged mass of the Salmon River Mountains. To the west are the

stark granitic highlands of the Idaho Batholith, with their ultimate expression in the Sawtooth Range; to the east, additional, less parallel ranges extend into Montana. The three mountain ranges, west to east, are the Lost River, Lemhi and Beaverhead; between them and west of the Lost River range are the broad tectonic basins known collectively as the Northeastern Valleys. Each valley extends from the Salmon River to Snake River Plain and has been divided into northwest and southeast draining basins by the uplifted Lemhi Arch (Dort, 1973). Southward draining streams, the Big and Little Lost Rivers and Birch Creek flow into a massive sink at the edge of Snake River Plain; northward flowing Warm Creek, Pahsimeroi River and Lemhi River are tributaries of the Salmon (Figure 2). The valley of the Pahsimeroi, situated between Lost River and Lemhi Ranges was the region chosen for this study.

The Pahsimeroi Valley is a long, broad tectonic trough, roughly 29 km between mountain crests and 64 km from head to mouth (Figure 3). On the east, the block faulted Precambrian and Paleozoic sedimentary rocks of the Lemhi Range rise abruptly from the piedmont surface to heights of 3100 m, while on the opposite side of the valley, the Lost River Range climbs more gradually to over 3700 m behind foothills of igneous origin (Figure 3; Bond, 1978; Mapel et al., 1965). Part of the Tertiary, Challis Formation, these foothills contain deposits of cryptocrystalline silicates and other glassy rocks. Some, particularly jaspers and chalcedonies of various forms, have precipitated from ground water into interstices and vesicles in the andesitic bedrock, while others, such as a glassy rhyolite are themselves of igneous origin.

The valley bottom is filled with Plio-Pleistocene alluvium and colluvium (Mapel et al., 1965; Ross and Forrester, 1958). The product of outwash from mountain canyons, primarily during glacial epochs (Funk, 1976), these alluvial fan deposits slope steeply from mountain fronts to the Pahsimeroi River (125 - 150 m/km, Figure 4) and more gently from the head of the valley at 2500 m a.s.l. to the Salmon River 1030 m below (80 - 125 m/km). As the valley filled,



Figure 2. Idaho's Northeastern Valleys, and vicinity. The Pahsimeroi Valley is just left of center. From Raiz Land Forms of the United States, 1949. Scale 1:1,000,000.



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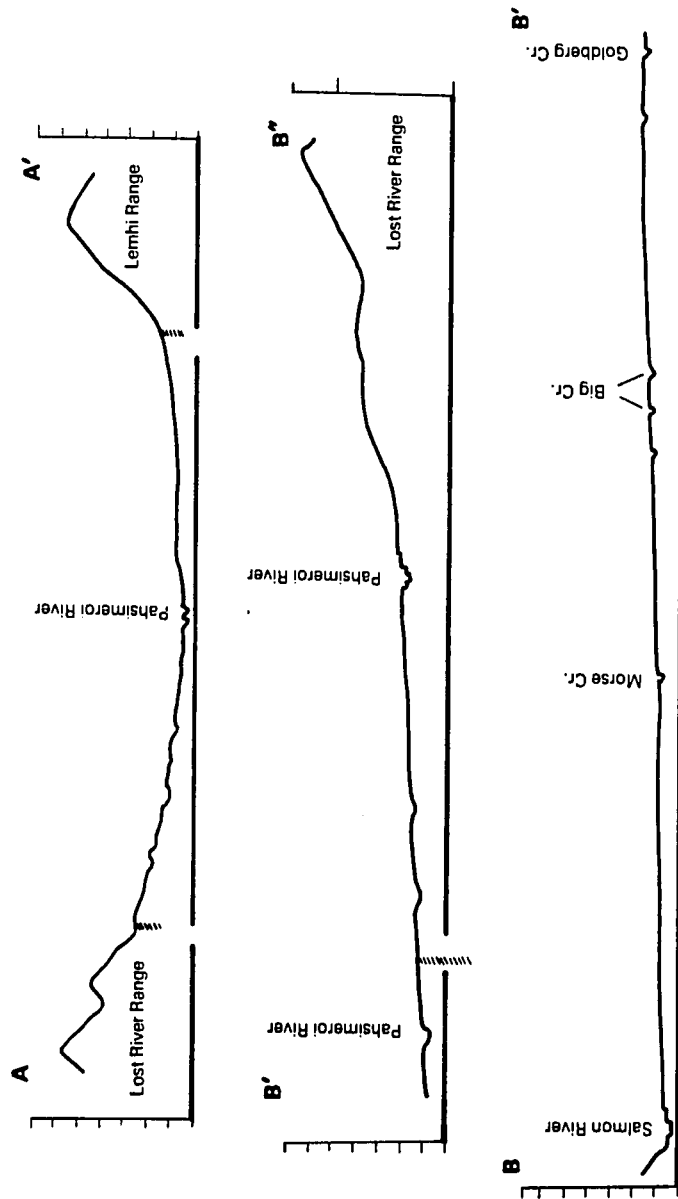


Figure 4. Cross-section and longitudinal section of the Pahsimeroi Valley.

cycles of tectonic uplift and subsequent erosion, especially evident in the portion of the valley affected by the Lemhi Arch, have resulted in the formation of numerous terrace levels along the valley's master streams.

Mountain fronts on either side of the valley are deeply incised by perennial and intermittent streams. On the Lemhi side, and the northerly half of the Lost River Range, these valleys are V-shaped at their mouths, while other streams, particularly those in the area of Lemhi Arch are U-shaped and filled with Pleistocene alluvium and glacial drift. These same canyons display a history of multiple glaciations, with moraines extending in some places at the valley head to elevations below 2400 m. Assuming this glacial sequence to be similar to that observed in the Upper Lemhi Valley (Dort, 1962; Knoll, 1977), Bull Lake, Pinedale, Temple Lake and Gannett Peak glaciations (Richmond, 1965) all are likely to be represented here. This was almost certainly true of Mt. Borah, the highest mountain in Idaho (3896 m) and the source of Pahsimeroi River, where a small glacier is still active (Ott, 1977).

That this area has experienced periglacial conditions in the recent past is evident from ubiquitous patterned ground features (cf. Fosberg, 1965) which occur on all alluvial surfaces except still-active floodplains above about 7000 feet elevation.

Where the streams have eroded through limestone, numerous small caves and rockshelters can be found, formed by dissolution and later widened from frost ablation. Caves are also common in tuffs and breccias of the Challis Formation, but are usually shallow and much smaller.

Hydrology

Each spring, swollen with snowmelt, small streams flow from every canyon in the Lost River and Lemhi Ranges. Except for four creeks; Mahogany, Burnt, Goldberg and Patterson and the Pahsimeroi River (Figure 3) which are all fed by high snowpacks in the Lemhi Arch, none of these streams remains active throughout the year.

Even during peak runoff, many of the small creeks emanate from their canyons only to seep into gravelly soil of their alluvial fans. Some streams, such as Doublespring Creek, enter alluvial gravels deep in their canyons, issue as springs near the canyon mouths and re-enter gravels after a short distance above ground. Water that sinks into the piedmont rises as springs in the valley bottom.

Today most water, especially that of perennial streams, is diverted into irrigation canals at the canyon mouth and distributed to farms at lower elevations. Sinking into the alluvium, much of this water rises again in the valley bottom, only to be used for irrigation a second time.

Small springs are also common mountain slopes, and although only a few produce sufficient flow to fill tiny streams, many remain moist throughout the year. The U.S. Forest Service, Bureau of Land Management and various private parties have opened these wet areas to collect water and divert it to stock watering troughs, often several kilometers away.

Several small lakes exist in the high mountains, most formed in moraine dammed cirques at the sources of Big Creek and the Upper Pahsimeroi River. Other lakes occur in landslide-formed basins near the south end of the valley in the mountain named Spring Hill (Figure 3). These latter bodies of water lie at elevations between 8000 and 7000 feet near the piedmont surface and are filled by springs and snowmelt.

Ultimately, all water that does not evaporate reaches the lower Pahsimeroi River, a stream with braided channels along the valley floor, which joins the Salmon enroute to the Pacific Ocean.

Climate

As a whole, the Pahsimeroi Valley is semi-arid, with the extreme aridity of the valley floor offset by more humid conditions found among mountain peaks. Mean annual precipitation at the weather station of May (1570 m, a.s.l.) is 20 cm (7.92", U.S. Weather Service 1978), while up to 76 cm (30") falls on nearby peaks

(Gerlach, 1970; Idaho Almanac, 1977). In the mountains, where frosts may occur at any time throughout the year, much of this moisture falls as snow.

The annual distribution of moisture is strongly skewed toward late spring and early summer, a characteristic pattern in the Northeastern Valleys Region (Table 1). Nearly one-third of the year's precipitation comes in May and June, with fall and winter months being the leanest.

The valley is cool, with mild summers and extremely cold winters. This again is characteristic of the Northeastern Valleys as a whole (Table 1). At May, the mean annual temperature is 5.8°C with January and July means of -8.3°C and 18.4°C respectively. The frost-free period is brief. At May, there may be as few as 60 days between killing frosts, although 90 is the mean (Anon., 1978). July is often the only frost-free period above 2500 m. This altitudinal gradient of temperature is often reversed during mid-winter, when high atmospheric pressure creates a temperature inversion and mountain peaks may be tens of degrees warmer than the valley below (Bill Hickey, personal communication).

Altitudinal temperature variations cause the almost constant winds experienced especially near the mountain fronts. Convection currents form between cool mountain tops and the warmer valley floor, sweeping cool air downslope during the day and warmer air up from the valley in the evening. During snowy winters, these winds can be a boon to large grazing animals, sweeping snow away from the mouths of canyons and creating what may often be the only snow-free vegetation at high altitudes during this season.

Biota

Altitudinal variations in temperature and precipitation result in high potential evapotranspiration in the mountains and extreme drought in the lowland. Distributions of the valley's major biotic communities follows this gradient, although geologic substrate and exposure to sun and wind also play a part. The valley and adjacent

Table 1. Climatic Data for the Northeastern Valleys Region*

	Monthly Means											Annual Mean*	
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.		Dec.
Temperature	-8.0	-4.8	0.2	5.8	10.8	14.7	19.2	18.0	13.0	7.2	-0.2	-6.3	5.8
Precipitation	1.7	1.3	1.2	1.6	2.8	3.3	2.0	1.8	1.8	1.5	1.4	1.7	22.9

*Temperatures are average values from 1917-1975; precipitation from 1895-1975. Values are in degrees Celcius and centimeters.

**Because older data were missing records for some months, annual mean is not the mean of the monthly values listed here. Data are calculated from annual records of the U.S. Weather Service.

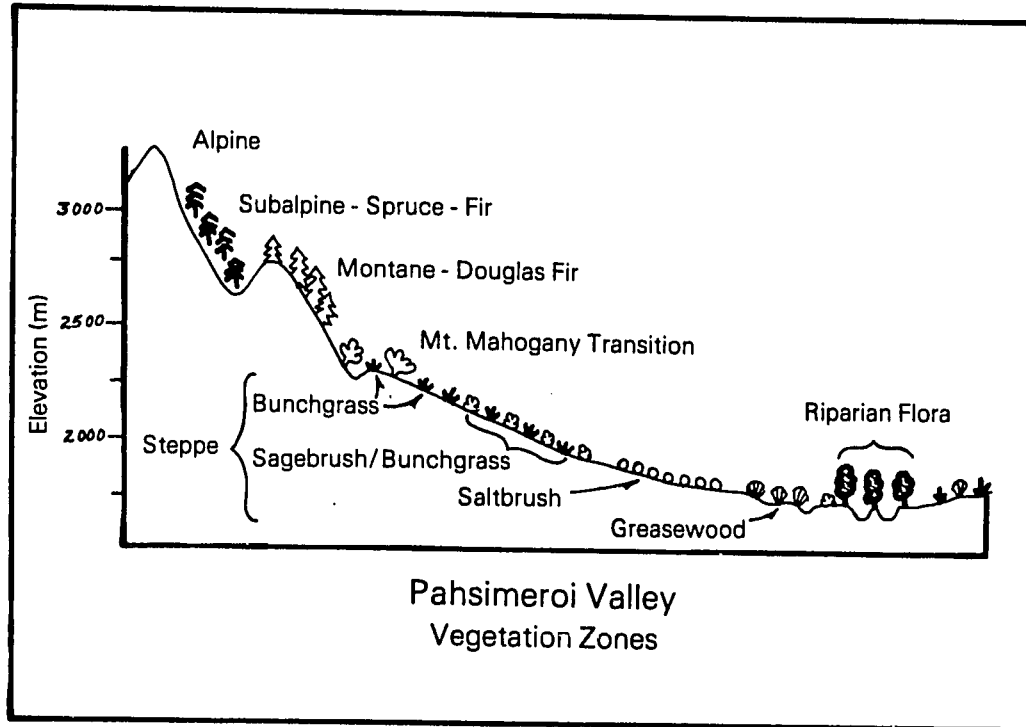


Figure 5. Altitudinal distribution of flora in the Pahsimeroi Valley. Mountain mahogany, saltbrush and greasewood stands are not universally distributed; their presence is dependent on edaphic and hydrologic conditions.

mountain ranges belong to the Great Basin and Central Rocky Mountain Biotic Provinces, respectively (Davis, 1939). More specifically, from lowest to highest elevations there are five principal vegetation zones: steppe, mountain mahogany transition, montane Douglas fir forest, subalpine spruce fir forest, and the alpine zone (Figure 5).

Steppe. Comprising the Great Basin Biotic Province, the vegetation from below around 2300 m is a semidesert dominated by sagebrush and various bunchgrass (Daubenmire, 1952). The dominant plants here are various forms of sagebrush (Artemisia esp. A. tridentata and A. aristata) and bluebunch wheatgrass (Agropyron spicatum). Various other grasses, forbs and brushy chenopods and composites are present in lesser amounts, and under special circumstances where moisture, soil type or exposure create the right conditions, some of these plants form dense, nearly pure stands. Saltbrush (Atriplex spp.) is common on alkaline soils at elevations below about 1750 m, especially in the northern half of the valley, and another chenopod, greasewood (Sarcobatus vermiculatus) grows around springs and seasonally wet areas in the valley bottom. Grasslands occur where north-facing slopes retain unusual amounts of soil moisture and at elevations above the normal steppe boundary where exposure prevents establishment of forest species.

Excessively rocky or sandy soils also support distinct, local communities. Vegetation is sparse on lithosols, but includes many species of forbs along with the drought resistant Artemisia aristata. Notable among the plants in lithosol communities is the edible bitterroot (Lewisia rediviva). Rabbitbrush (Chrysothamnus spp.) forms small, almost pure patches on fine soils of periglacially-formed frost polygons.

A riparian association occurs where ground water comes to the surface, commonly along perennial streams and around springs and lakes. The ground is carpeted by short grasses and sedges (Carex spp.) and forbs such as dandelion (Taraxacum spp.), wild onion

(Allium spp.) and iris (Iris missouriensis). Where conditions are most moist, usually where surface water occurs, willows (Salix spp.) form thickets with wild rose (Rosa cf. woodsii) and gooseberry (Ribes spp.) and an overstory of willow.

Animals inhabiting the steppe are those birds, mammals and reptiles which compete well under open, arid conditions. The most numerous creatures in the sagebrush-bunchgrass steppe itself are various mice, principally deer mice (Peromyscus maniculatus), great basin pocket mouse (Perognathus parvus), sage vole (Lagurus curtatus), and various ground squirrels (Spermophilus spp.); the California jackrabbit (Lepus californicus) and pygmy cottontail (Sylvilagus idahoensis; Davis, 1939). Pronghorn (Antilocapra americana) and domestic cattle (Bos taurus) are the dominant large herbivores, with the former occurring in natural populations of several thousand. Pika (Ochotona princeps) and yellowbellied marmot (Marmota flaviventris) live in talus slopes.

Some birds are exclusive to the steppe, such as the horned lark (Eremophila alpestris), sage grouse (Centrocercus urophasianus) and various sparrows and songbirds. Others, the long billed curlew (Numenius americanus) and various ducks are seasonal migrants. Coyote, (Canis latrans), bobcat (Lynx rufus), badger (Taxidea taxus) weasels (Mustela spp.), rattle snakes (Crotalus spp.), golden eagles (Aquila chrysaetos) and several hawks and owls are the area's common predators.

Localized plant associations within the steppe support distinct faunas, with that of the riparian association being the most diverse. The riparian community with its grass, brush and tree components, is vertically zoned. Numerous species of birds, including magpie (Pica pica) and red shafted flicker (Colaptes cafer), share the upper storey of trees and willows with red squirrels (Tamiasciurus hudsonicus) and flying squirrels (Glaucomys volans). Jumping mice (Zapus princeps), meadow voles (Microtus montanus) and Nuttall's cottontail (Sylvilagus nuttallii) and various ground squirrels and the northern pocket gopher (Thomomys talpoides) live at or below

ground level. Mule deer (Odocoileus hemionus) can often be seen in this environment, where they find forage and shelter.

The riparian zone also has aquatic habitats and their associated fauna. Beavers (Castor canadensis) construct large water-retention dams along smaller streams, forming extensive willow swamps and large ponds that are the ideal habitat of native rainbow (Salmo gairdneri) and the introduced eastern brook trout (Salvelinus fontinalis). Silts deposited behind these dams are the substrate on which much of the riparian flora now thrives. More rapid water is a favorable habitat for the small sculpins (Cottus spp.) and a few of the rainbow trout. Lower in the valley, these species are joined by muskrat (Ondatra zibethica), and various species of waterfowl. King salmon (Oncorhynchus cf. tschawytscha) and steelhead (Salmo gairdneri) spawn in the broad, lower river during summer and early fall, and once were an important source of food to the area's native inhabitants (Steward, 1938; Thwaites, 1905).

Transition zone. This chaparral-like flora occurs in scattered locations between the steppe and conifer forests of the higher mountain slopes (Figure 5). Mountain mahogany (Cercocarpus ledifolius), a large evergreen bush of the rose family is the dominant plant here, often growing to over 5 m in height and effectively shading out all shorter plants. Other species common to the transition zone are bitterbrush (Purshia tridentata), serviceberry (Amelanchier spp.) and buckbrush (Symphoricarpos spp.; Davis, 1952). Transition vegetation commonly occurs on rough, thin soils or on steep exposed mountain slopes, where steppe and forest are at a competitive disadvantage. Providing cover, berries and year-round browse, this chaparral is excellent habitat for mule deer and black bears (Ursus americanus). Several species of grouse and song birds also find this habitat favorable.

Montane Douglas fir forest. The Central Rocky Mountain biotic province of Davis (1939) consists of the conifer forests and alpine

meadows of moist mountain slopes. Daubenmire (1952) recognizes three coniferous forest communities in this province of Central Idaho which are correlated with elevation; the lowest is the ponderosa pine zone, an association of Pinus ponderosa and a steppe understory which is largely absent from the Pahsimeroi Valley. The second zone, Douglas fir forest, is common. The community is made up almost entirely of Douglas fir trees (Psuedotsuga menziesii glauca). Stands of this species are dense and often virtually impenetrable, except near the lower forest border, at exposed sites or where the forest is of great age. In older stands, or on dry or windswept ridges, the canopy is more open and an understory of brush or steppe can be found. Other conifer species occasionally occur in this zone and mingle with the Douglas fir at higher elevations. Limber pine (Pinus flexilis) and lodgepole pine (Pinus contorta) are common, but alpine fir (Abies lasiocarpa), whitebark pine (Pinus albicaulis) and Engleman spruce (Picea englemanni) also occur.

Animals are neither varied nor abundant in this dense forest. Tree squirrels, porcupine (Erithizon dorsatum), red-backed mouse (Clethrionomys gapperi), golden mantled ground squirrel (Spermophilus lateralis), various grouse and songbirds and the pine marten (Martes americana) are all most common here and in the subalpine spruce-fir forest. Mountain lion (Felis concolor), coyote and bobcat also frequent this habitat, finding an abundance of their prey (Davis, 1939).

The same trees occur here as in the lower forests, but Engleman spruce and alpine fir are the most numerous. At the upper tree line, nearly 10,000 feet in both mountain ranges, trees are gnarled and windswept. Many of the pines, especially the limber pine, are extremely large here, often reaching diameters of 1.5 m and more in protected areas. A krumholz zone occurs in places, but more often seen are the ice blasted remains of hugh pines as much as a 100 m above the present tree-line. Gnarled, ancient limber pine and Douglas fir also occur on windswept or rocky slopes in the Douglas fir zone.

Alpine zone. This is a sparse community of grasses, forbs and dwarf species of woody plants that grow on fine soils of glacial drift or in protected hollows above tree-line. Voles (Phenacomys longicaudus and Microtus richardsoni) and gophers are the only small mammals here, and they share the rocky highlands with small populations of mountain goats (Oreamnos americanus) in the Lemhi Range and bighorn sheep (Ovis canadensis) in the Lost River Range. Once very abundant, according to the valley's older inhabitants, bighorns were locally extinct by the 1930's. The Idaho Fish and Game Department reintroduced a dozen animals from Banff National Park in 1969 and the species is now beginning to recover its range (Bill Hickey, personal communication).

These vegetation zones are by no means universal to every mountain slope, and the transition zone and one or both kinds of forest are often absent. It is not at all unusual to see steppe and alpine zones with no intervening cover, although the steppe is gradually more dominated by grass as elevation increases. Such open areas form natural corridors through which bighorn once migrated to lower elevation winter pastures and through which pronghorn now occasionally proceed to alpine meadows in the height of summer.

History and Modern Human Habitation

Until the mid-nineteenth century, the rugged mountains of Central Idaho were the home of the Tukudeka or Sheepeater Shoshone (Liljeblad, 1972). These people lived in small, loosely organized, highly mobile bands and foraged over large territories, seasonally gathering salmon from the larger rivers in summer, hunting large mammals in fall, winter and spring, and gathering numerous species of edible roots as they became available (Cutright, 1969; Liljeblad, 1972; Steward, 1938). In the 18th century, some of the most easterly Shoshone, including the Lemhi Valley population, acquired horses and soon accepted a plains equestrian style of culture. These folk annually migrated to the plains of Montana to hunt bison, and although they still fished and gathered roots (cf. Thwaites,

1905), became quite distinct from the western neighbors. Most Central Idaho Shoshone, living in rugged, mountainous terrain, remained pedestrian until they were forced onto reservations in the 1870's.

After Lewis and Clark's 1805 visit to the Lemhi Shoshone, Euro-American traders and trappers began to enter Idaho in the 1820's and 1830's, and have provided us with early descriptions of what was then a more mesic environment (cf. Fremont, 1945). Beside these transients, permanent Euro-American settlements existed only at Hudson's Bay Company Forts Boise and Hall, both on the Snake River Plain. Wagon trains bound for Oregon did not stay in this relatively forbidding land, but continued westward until 1860, when gold was discovered in the west-central mountains, and the Mormons began to settle Bear River Valley. These early settlements, which soon expanded along the Snake and other large rivers, especially around Boise, disturbed the equestrian Bannock and Shoshone of the plain and Nez Perces of the lower Salmon, Clearwater and Snake, but left the mountain Tukudeka pretty much alone until the 1870's. Some had even begun to accept the Euro-American mode of subsistence, and about 200 had settled in a colony on the Payette River (Liljeblad, 1972).

In the 1870's, metals - nickel, silver and lead, were discovered in the Lemhi and Beaverhead Ranges, and miners began to enter the region. At about the same time, 1875, the Lemhi Indian Reservation was formed and some of the remaining Tukudeka began to settle there with the equestrian Lemhis. Finally, during the "Bannock Wars," many of the Payette Tukudeka left their farms and fled into the rugged central Idaho mountains, where in 1879, troops captured 50 at the mouth of Big Creek. How many other Tukudeka continued to exist in the Idaho Primitive Area after that date is unknown (Liljeblad, 1972).

Native peoples had then been driven from the Pahsimeroi Valley, probably by the 1870's, when a few miners and stockmen began to filter across the Lemhi Range from mines in the Lemhi Valley

(Epperson, 1980). These first settlers established homesteads and stock raising operations, first in the lower, northern section of the valley, and by the early 20th century had expanded into the upper portions of the valley. In 1900, there were 260 people in 62 households (Epperson, 1980 - note that Table 2 lists 199 for this period because the Sunol census district is excluded from the total). The number of households the valley could sustain was limited by availability of irrigation water which was needed to raise hay for the winter feeding of thousands of sheep, cattle and horses (cf. Rouse, 1973).

Table 2. Census Data for Precincts in the Pahsimeroi Valley, 1890 - 1970.*

County Precinct	Census Year								
	1890	1900	1910	1920	1930	1940	1950	1960	1970
Custer									
Pahsimeroi	84	44	159	88	110	74	67	?	?
Sunol	?	61	94	?	54	83	87	?	?
Lemhi									
Pahsimeroi			181	339	210	228	174		
Patterson	-	155						340	185
			91	98	98	293	204		
Total Population (less Sunol District)	84	199	431	497	418	596	445	340	185
Total with Sunol	84	260	525	-	472	679	532	-	-

*Question marks denote a lack of data due to combination of the Pahsimeroi Precinct of Custer County into a larger administrative unit including the city of Challis. Pahsimeroi and Patterson Precincts of Lemhi County were combined before 1910 and after 1950, and a single value is given. The Sunol Precinct of Custer County is often missing from the records. Source is Bureau of the Census (1910, 1932, 1953, 1963, 1973).

Three small towns were established in the early- to mid-twentieth century: May, Goldberg and Patterson. The former two were apparently market centers, but the latter was principally a mining town. All three are now ghost towns, or have but a few inhabitants. There is other evidence of a decline in population during this century, manifest in numerous abandoned farmsteads scattered about the valley. Census records confirm the decline (Table 2). With the Sunol District excluded because it was often incorporated with a portion of the Salmon River Valley (Sunol is the lowest few miles of the Pahsimeroi's west bank and the adjacent Salmon River Floodplain [Bureau of the Census, 1932]), the area's population rose from 84 in 1890 to over 400 from 1910 to 1950. Estimating the modern population of Pahsimeroi and Sunol districts at not over 100, based on the small number of occupied farms in that area, there were no more than 285 people in the valley in 1970.

Until recently, the people still lived by a mixture of pastoralism and irrigation farming, the Patterson mines having closed down from the 1940's until 1980. Most of the valley's land is left in range and forest (92%), with only about 4 percent in irrigated pasture or crops (McAlindin and Porter, 1980). Farms are situated on the piedmont, near the perennial streams, and along the valley bottom, and all but one are below 2000 m elevation. The principal crop is hay used to feed the thousands of cattle raised on federal range lands. Some sugar beets, potatoes, sheep, horses and hogs are raised, but the valley's economic base is cattle.

The herds are moved in an annual cycle, beginning in spring, when cattle and new calves are turned out onto the steppes to graze the now sparse bunch grasses. The maintenance of too many animals on public pastures has been blamed for an increasingly brushy steppe (cf. Idaho Almanac, 1977). Cattle remain on the range, usually into the fall, when they are rounded up and transported to lower elevations to be fed hay over the winter. Many herds are left on the range year-round and are fed a supplement of hay there, also.

Except for the few animals slaughtered for home consumption, cattle are sold as yearlings to feedlots and monies from the sale of this and other agricultural products is used to purchase foods, lumber, automobiles and other consumer goods, usually bought outside the valley.

Use of higher elevation steppes and mountainous terrain is limited, and human presence is uncommon above 2000 m, consisting primarily of brief seasonal visits to hunt and fish during summer and fall. Most hunters and fishermen who come to extreme elevations seem to be outsiders; locals are surprisingly unfamiliar with more remote parts of their valley.

Today, several years after I completed fieldwork on this study, conditions are changing rapidly. A huge, open pit mine some 60 miles northeast of the valley has brought 7000 new people to the area. The Patterson mine has been reopened and prospecting for fossil fuels in the valleys has begun. Thus, the modern patterns of settlement and land use which I describe in subsequent chapters may already have become things of the past.

Archaeological Resources

The prehistory of east central Idaho has been studied most extensively by the late Earl Swanson, B. Robert Butler and their students, although more recent investigations have been conducted by archaeologists from federal agencies (cf. Harrison, 1981), largely as an aspect of land management planning (cf. Epperson, 1977; Kingsbury, 1977). During the 1960's, Swanson and Butler conducted extensive research in the Birch Creek Valley (Ranere, 1971; Swanson, 1972; Swanson and Bryan, 1964; Swanson and Sneed, 1966; Swanson et al., 1964), in an attempt to test the hypothesis that the ethnographic Tukudeka Shoshone were not late comers to the Rocky Mountains (cf. Lamb, 1958; Steward, 1938), but were merely the terminus of a continuous cultural tradition that had existed in the area since the terminal Pleistocene. In the process of his excavations, Swanson excavated three well stratified rockshelter sites in

the Birch Creek Valley (Ranere, 1971; Swanson, cf. 1972), two on the Salmon River near the confluence of main Salmon and North Fork Salmon Rivers (Swanson and Sneed, 1966) and one near the mouth of Little Lost River Valley (Swanson and Sneed, 1971), recovering deposits dating back to 11,000 BP.

In analyzing his findings, Swanson (1972) developed a local chronology of five phases (Table 3), which he correlated with six climatic cycles inferred from geologic deposits at Bison (10CL10), Veratic (10CL3) and Shoup (10LH23; 10LH63) Rockshelters. After comparing artifact assemblages and faunal inventories from these phases, he observed that the populations, hunting strategies and altitudinal distributions of the area's prehistoric inhabitants vary in response to the inferred changes in climate and consequent changes in the distribution and size of bison and bighorn sheep populations. Finally, because of apparent continuities among projectile point styles, he surmised that a single cultural tradition had existed in the region at least since 7000 BP. His conclusion: a single human lineage, Shoshonean, had inhabited Central Idaho throughout the Holocene, continuously pursuing a foraging mode of subsistence concentrated on the hunting of big game, but responding to long-term variations in the regional environment while evolving increasingly efficient strategies for acquiring resources.

More recently, after excavations of his own at the Challis Buffalo Jump (10CR196, [Butler, 1971]), and subsequent re-evaluation of artifacts from Birch Creek sites and the Little Lost River Cave No. 1, Butler (1981a, 1981b) has come to different conclusions. Concentrating more on the stylistic differences among artifact styles, particularly projectile points, ceramics and basketry (rather than their similarities, as Swanson [1972] had done) Butler believes that distinct ethnic groups entered the Northeastern Valleys on two separate occasions. Fremont peoples from Utah and/or Athabascans from the Northern plains invaded the region at the beginning of the Blue Dome Phase, which he places at 500 AD (Butler, 1981b, note the difference with Swanson, 1972; Table 3), bringing

with them small Avonlea-like (Kehoe, 1966; Kehoe and McCorquondale, 1961) side-notched projectile points and Fremont style coiled basketry. Subsequently, as late as 1800 AD, Shoshoneans supplanted these people, bringing with them the desert side-notched projectile point and ushering in the Lemhi Phase (again, note the difference from Swanson's data for the beginning for this phase [Table 3]).

Table 3. Archaeological Phases and Climatic Episodes*

Date	Archaeological Phase	Climatic Episode
AD 1250 to 1850	Lemhi	Period VI, briefly dry, then cool and moist, but less so than Periods II and IV.
950 BC to 1250 AD	Blue Dome	Period V, "arid, then cool and moist, turning semi-arid but not uniformly so."
1450 to 950 BC	Beaverhead	Period IV, "cool, moist".
5200 BC to 1450 BC	Bitterroot	Period III, "Primarily arid but later alternating with semi-arid conditions."
9000 BC to 5200 BC	Birch Creek	Period II, "Primarily cold and moist but drier at beginning and end."

*As defined by Swanson for the Birch Creek Valley (1972: pp. 63, 65).

Although I subscribe to neither position and prefer to remain outside such a debate, the arguments of Butler and Swanson do serve to flag the Northeastern Valleys as an area in which interesting changes have occurred, some of them at least purportedly related to human adaptation in the face of changing environments (cf. Butler, 1978; Swanson, 1972). The Pahsimeroi Valley therefore appeared to

be an area where a study of the type outlined in Chapter 2 might be profitably conducted.

That the valley contains an archaeological record adequate to the task I have proposed is evident from the results of surveys conducted by Idaho State University (Swanson et al., 1959, 1969). During the later survey, actually an unsystematic reconnaissance of the entire Salmon District of the BLM, 47 archaeological sites were recorded in the valley. Swanson, King and Chatters (1969) compared the density of Pahsimeroi Valley sites with site densities in adjacent valleys, and concluded that along with the Salmon and Big Lost River Valleys, the Pahsimeroi had been a center of aboriginal occupation while more easterly valleys had served merely as seasonal food gathering locales. These conclusions, biased as they were by the distribution of federally owned lands and severely handicapped by the lack of any systematic research design, cannot be supported with the data from which they were generated. However, the survey did serve to demonstrate the valley's archaeological potential.

During the survey, King and I became aware of the generally surficial nature of most sites, observed several localities with potential for stratified cultural deposits, and noted apparent temporal variations in the distributions of projectile points. It was also evident from this research and later reports of Folsom points at the valley mouth (Butler, 1972a) that habitation of the valley had begun by 10,000 years ago. I surmised from these observations that the valley would be a good area to study changing patterns of human adaptation: artifacts were common on the surface and seemed to indicate some degree of change over the 10,000 year period of human activity. Preliminary investigations in 1973 and 1974 (Chatters, 1976c) added tentative confirmation.

Archaeological resources of the Pahsimeroi are not confined to the prehistoric lithic scatters and occasional stratified sites, but cover the Euro-American period as well. Abandoned farmsteads, irrigation systems and trash dumps, many of them now well above the modern altitudinal limit of permanent settlement, are all visible

and bespeak changes in adaptation and population size, to which I have already alluded. Because of the semi-arid climate, sparse ground cover and general absence of recent sedimentation over most of the land surface (cf. Funk, 1976), both Native American and Euro-American artifacts are readily visible and amenable to the surface collection strategy I had intended to employ (Chapter 4).

Potential for Paleoenvironmental Data

Prior to this investigation, no paleoecological studies had been conducted in the Pahsimeroi Valley. In fact, only a few such studies had yet been conducted in the Northeastern Valleys as a whole. Swanson's (1972) analysis of rockshelter stratigraphy in the Birch Creek and Salmon River Valleys is on Table 3, and the relative chronology of glacial still-stands in the Lemhi Mountains by Dort (1962) and Knoll (1977) is a second. Both bespeak numerous, at least minor, climatic changes during the Holocene, but neither provides a reliable basis for constructing a regional sequence of climatic events. A record of late Pleistocene faunas has also come from Jaguar Cave in the Northeastern Valleys (Guilday and Adam, 1967; Kurten and Anderson, 1972; Sadek-Kooros, 1972), but the geologic history of this site was originally misinterpreted (Dort, 1976), bringing into question all conclusions about the faunal changes during the late glacial and early post glacial periods.

Butler (1978) has recently used records of pollen from Swan Lake at the Utah-Idaho border (Bright, 1966) and of small mammals from the Wasden site (Guilday, 1969; Butler, 1972b, 1972c) along with data from Wilson Butte Cave (Gruhn, 1961) and the Northeastern Valleys to develop a tentative sequence of what he calls "climatic-ecologic" periods. These are as follows:

Period I. Ca. 15,000-13,000 B.P.
Cool to cold; extensive alpine glaciers in mountains north of Snake River Plain; probably tundra conditions in the valleys north of the Snake River Plain; coniferous forest probably covers many of the valleys south of the Snake River Plain,

encroaches on the Plain itself, covering higher prominences and ridges on the Plain; lodgepole and limber pine dominant in much of this coniferous forest; spruce also in abundance, but Douglas fir scarce or absent; sagebrush-grass vegetation present in parklands and on the Plain, but marshes and wet meadows also present; typical Late Pleistocene (Rancholabrean) fauna present.

Period II. Ca. 13,000-11,400 B.P.

Still cool, but warming trend (deglacial hemicycle) has begun; this trend will be interrupted by intervals of very cold temperatures resulting in glacial stillstands in the mountains and permafrost conditions on the Snake River Plain at intervals of approximately 1,800-2,000 years; glacial melt increasing, resulting in high runoffs in the major rivers and the construction of high terraces along these rivers; tundra conditions still present in the valleys north of the Snake River Plain, but ameliorating; coniferous forest still present at lower elevations and on the Plain; however, changes in biota are beginning to occur; by end of this period, elephants, which were never very numerous in this region, are becoming extinct along with certain specialized carnivores such as the saber-tooth cat.

Period III. Ca. 11,400-10,800 B.P.

Still cool, but definitely warmer than before; marked decrease in spruce at lower elevations; distribution of lodgepole and limber pine beginning to change; sagebrush-grass vegetation may be becoming more abundant; by the end of the period, camel and horse may have become scarce and elephant extinct.

Period IV. Ca. 10,800-8,400 B.P.

Warming trend, interrupted by cold pulses, continues; coniferous forest retreating from lower elevations; lodgepole and limber pine becoming less important, Douglas fir more important; sagebrush-grass vegetation expanding with grasses equal in importance to sagebrush; among the small animals associated with the sagebrush-grass biome, the northern pocket gopher is dominant (see earlier discussion); among the large game animals, Bison antiquus is probably at a maximum in the lower valleys and on the Plains, while mountain sheep are expanding in the mountains.

Period V. Ca. 8,400-7,200 B.P.

The long-term warming trend has reached a point where temperature and moisture conditions are becoming acute for survival of Late Pleistocene ecosystems; although there are still remnants of Pleistocene alpine glaciers in the mountains and cyclical cold pulses capable of producing periglacial conditions on the Snake River Plain, there is a very substantial rise in the numbers of the dry-adapted Townsend pocket gopher; however, the northern pocket gopher and pygmy rabbit, although evidencing some decline in maximum numbers, are still dominant among these small animals; Bison antiquus is clearly present early in the

period but evolving towards the modern form of bison (Bison bison); both camel and horse are extinct by the end of this period.

Period VI. Ca. 7,200-3,800 B.P.

At ca. 7,200 years ago, the trend towards increasing warmth and dryness reaches a point where the grasses begin to fail and there is an abrupt shift in the composition of the small animal community in favor of the dry-adapted forms; some cold pulses early in period, but alpine glaciers completely gone by ca. 6,500 years ago; forest greatly reduced in total area; carrying capacity of sagebrush-grass ecosystem steadily declines; warming trend culminates in episode of maximum warmth and dryness ca. 3,800 years ago; this period is the first phase of the Holocene epoch.

Period VII. Ca. 3,800-2,800 B.P.

Return to cooler, moister conditions, glaciation in the mountains, and increased carrying capacity of regional ecosystems; a grassland maximum.

Period VIII. 2,800-650 B.P. (300 B.C.-A.D. 1300)

Trend to increasing warmth and dryness again; bison appear to begin to increase in numbers; climatic cycles of less than 1,000 years in length become increasingly important.

Period IX. 650 B.P.-Historic (A.D. 1300-1805)

Episodes of glaciation in mountains, though not as great as in Period VII, and also episodes of drought; short climatic cycles important; modern bison continues to increase in number. (Butler, 1978:43-45)

While climatic and biotic changes interpreted by Butler may differ in kind, amplitude and age from changes which actually occurred in the Pahsimeroi Valley, these data do suggest that along with the rest of Western North America, marked ecological changes may have occurred in the Pahsimeroi area during the Holocene.

Potential sources of data that could be used to investigate Holocene environmental change do exist in the Pahsimeroi. They take the form of lakes and springs, from which pollen records could be obtained, caves in limestone and breccia that contain both faunal remains and macroscopic plant fossils and glacial moraines and other geologic deposits plus ancient trees and fossil tree lines that could be used to infer a climatic history of the area. Consequently, the valley seemed to contain the paleoenvironmental data so necessary to this study and was likely to exhibit changes in local climate and biota to which the local inhabitants would have to adapt.

The Project Area

The area I chose for the present investigation is the south end of the Pahsimeroi Valley (Figure 6). Its boundaries are: the 1950 m contour on the north, the crest of the Lemhi Range on the south, a line down the center of Doublespring Canyon on the west and to the east the Pahsimeroi River to its confluence with Long Creek and thence along the divide between the basins of Burnt and Long Creeks. In all, these boundaries encompass over 200 square kilometers of alluvial plains, canyons and mountain slopes.

The area is known as the Upper Pahsimeroi Valley and is geographically separated from the rest of the valley by the steeper slope of its alluvial plain that has been caused by uplift of the Lemhi Arch. It consists of a 14 km by 6.5 km alluvial plain marked by numerous terrace levels and surrounded on three sides by mountains of varying height. Mount Borah and Leatherman Peak, the highest ground in Idaho lie to the south and east, Spring Hill, an isolated block of Mississippian limestone and Tertiary volcanics surrounded by Horseheaven Pass (a broad canyon), Doublespring Canyon and the open plain, occupies the northwest quarter and Donkey Hills, also a mixture of Tertiary and Paleozoic formations lies to the east. Total relief is over 1850 m.

I chose this segment of the valley for six reasons:

1. It is isolated and rarely visited by people and is therefore likely to have been less subject to looting by amateur artifact collectors.
2. It was known from the 1966 survey (Swanson et al., 1969) to contain an abundance of surface artifacts of both Native American and Euro-American origin.
3. Buried archaeological deposits were known to exist and, due to the aridity of the area and calcareous substrate could be expected to contain faunal remains and, in a burned state, floral remains.
4. Small caves are present, especially in Doublespring Canyon and around Spring Hill, and more than half the valley's lakes exist

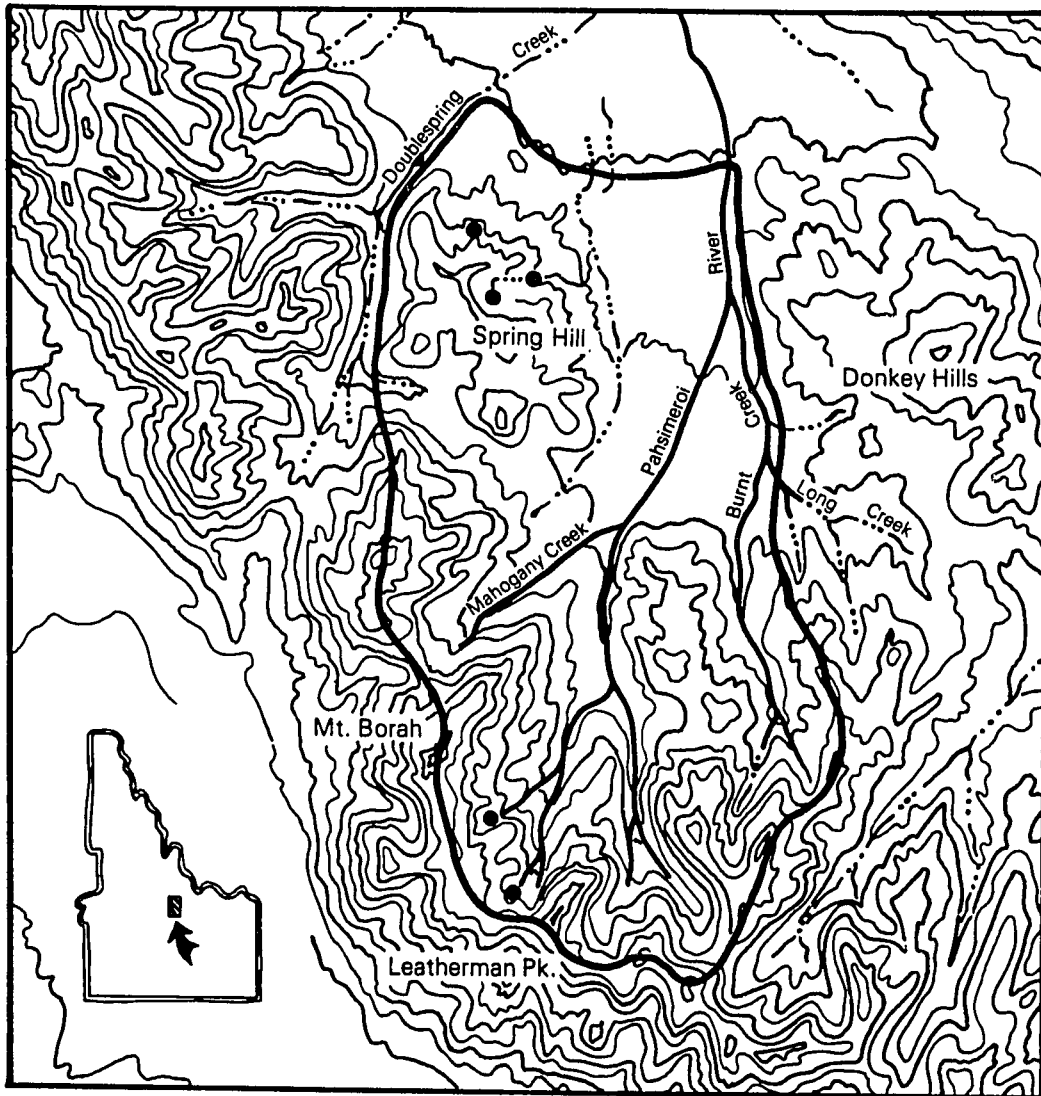


Figure 6. The Project Area, enclosed by a heavy line, showing landmarks referred to in the text. large black dots are lakes. From USGS Dubois Quadrangle. Scale 1:250,000.

on Spring Hill and high in the Lost River Range, and potentially contain a long record of paleoenvironmental change.

5. Ancient trees, some initially estimated at 1000 or more years old are common at both upper and lower tree-lines and could be studied to obtain a climatic record for the last millenium.

6. The area appeared to have been geologically stable during Holocene time, with only minor changes in the narrow floodplains of existing streams having occurred since glacial outwash ceased and alluvial fans stabilized (Funk, 1976). The probability of geologic change having altered distributions of minerals, water or biota was therefore slight, the importance of this variable was thus likely to be minor at most, and the study would be thereby simplified.

Within the Upper Pahsimeroi Valley, research was limited to the steppe zone (Figure 6), a decision made purely on logistic grounds. First, surface visibility in this area was excellent, but was non-existent in the forested areas, even when one could penetrate the thickets of Douglas fir, alpine fir and spruce. The second consideration was financial: funds were insufficient to permit hiring a string of pack mules and the larger field crew that would have been necessary for adequate coverage of the high peaks.

Specifically, this study covers the alluvial floor of the Upper Valley as a whole, flat-bottomed canyons of Mahogany Creek, Burnt Creek, and the upper Pahsimeroi River and the low foothills between them, much of Spring Hill, including the huge, late Pleistocene landslide emanating from the hill's east flank, and a portion of the floor of Doublespring Canyon. Archaeological, palynological and paleontological data all were acquired from the steppe or steppe-forest edge. Tree-ring data used in climatological studies necessarily came from the lower forest border.

The following investigations thus consider human adaptations in the steppe zone of the Upper Pahsimeroi Valley and the response of those adaptations to changing Holocene climates.

CHAPTER FOUR

Adaptive Patterns: Data Collection Strategy and Field Tactics

Intensive surface survey is the field method which has produced the best results in studies of adaptive patterns (e.g., Dancey, 1973; Doelle, 1977; Dunnell et al., 1973; Chatters, 1980a; Goodyear, 1977; Rice, 1975; Thomas, 1971a, 1973; Williams et al., 1973). The specific procedure used in the Pahsimeroi study was siteless survey (Dancey, 1973, 1974; Dunnell and Dancey, 1981), a technique in which the entire surface of each sample unit is searched and the precise location and microenvironmental position of each artifact is recorded (see also Doelle, 1977; Goodyear, 1977; Davis, 1975). The value of this approach lies in its explicit environmental orientation and its concern with the location and study of isolated artifacts and small or low density artifact scatters (Schiffer et al., 1978:2 or "nonsites" Thomas, 1975), which represent diffuse resource acquisition and processing activities (cf. Hayden, 1978), as well as the denser aggregates of objects commonly referred to as sites.

Siteless survey is substantively different from the nonsite sampling form of intensive survey employed by Thomas (1975) in which artifacts not found in dense aggregates were collected as a unit from the surface of large (250,000 square meters) sampling areas. Nonsite sampling, while permitting the investigator to observe large scale changes in artifact distributions among macroenvironmental zones (Thomas, 1971a, 1973) precludes the investigation of changing land use patterns with respect to small scale environmental variables. This problem is not associated with siteless survey.

Collection of records on precise locations of individual artifacts has an added advantage in that it allows analytic separation of temporally distinct occupations from large surface scatters.

Careful studies of lithic materials and artifact style distributions can often be used to break large aggregates into distinct occupations, as I shall demonstrate in a later chapter (cf. Binford et al., 1970). Such an analysis is rendered impossible when artifacts are gathered using the site as a collective province.

Sampling

As is the case with most regional studies of archaeological patterning, (e.g., Matson and Lipe, 1975; Mueller, 1974; Plog and Hill, 1971), time and funding constraints precluded the intensive investigation of the entire Project Area. In fact, with the application of the siteless survey technique, a labor intensive procedure in which point province is recorded for each artifact, it is rarely possible to investigate more than a small fraction of the target universe (cf. Dancey, 1973, 1976; Doelle, 1977). So that conclusions about the evolution of adaptive patterns in the Upper Pahasimeroi Valley could be drawn with confidence on the basis of findings from a small portion of the total area, some form of sampling design had to be employed. That sampling design had to be devised such that the relationship between the sample and the entire project area was known beforehand and expressed in operational terms.

With the rise of regional studies as a component of the archaeological research design (Binford, 1964) the problem of sampling has received extensive review (e.g., Cowgill, 1964; Hole, 1980; Mueller, 1975; Redman, 1974) and numerous tests of various probabilistic sampling designs have been conducted (e.g., Mueller, 1974; Judge et al., 1975; Matson and Lipe, 1975; Plog, 1976). Notwithstanding more than a decade of discussion and analysis, there is no consensus on which kinds of sampling designs are most effective for regional surveys (Schiffer and Gummerman, 1977; Schiffer et al., 1978). While most authors insist that sampling designs must be probabilistic to provide valid information about a target population of archaeological material (e.g., Binford, 1964;

Read, 1975; Judge et al., 1975; Collins, 1975), some experiments have shown that non-probabilistic samples (i.e., those which are not based on random selection of sample units) can provide adequate data on variability in the archaeological record (Mueller, 1974), can be more accurate and precise predictors of population parameters (Judge et al., 1975), and may in some cases be more efficient than probabilistic designs (Muller, 1974; Plog, 1976). No single sampling design is best for all circumstances. The choice of a given sampling design is therefore dependent on the nature of the problem under investigation, the characteristics of the region in which research is to be conducted, and the constraints of time and financial resources faced by the investigator (Schiffer et al., 1978; see also Read, 1975). As Schiffer and Gummerman point out,

Appropriate sampling designs derive from creative interplay between sampling expertise, nature of the study area, and research and management needs. (1977:185)

In the Pahsimeroi Valley study, I was concerned with evolution in patterns of land use and settlement as aspects of a pattern of adaptation to the upper steppe zone environment. More precisely, I required data on the specific habitats within the project area that were exploited by the area's human occupants. This necessitated coverage of each potential habitat in equivalent proportion and, for greatest accuracy in obtaining information on the total variability of habitat utilization, that those potential habitats be defined on the smallest scale feasible. This task also had to be accomplished with a maximum of approximately 1500 man hours of labor.

The scheme employed was a form of multilevel stratified sampling (Mueller, 1974:29) in which the sample universe (the entire study region) was divided first into classes of redundant physiographic units, each of which was then divided into micro-environmental strata. Three classes of physiographic features, called tracts were identified, including tributary canyons with intermittent streams, tributary canyons with permanent streams, and

segments of the alluvial valley bottoms. Each tract was further stratified into microenvironments on the basis of small-scale topography. Plant communities were not used in stratification because although they clearly bear a closer relationship to subsistence activities and have been used effectively elsewhere (Doelle, 1977), floral associations are subject to change in distribution and content with changing climatic conditions (cf. Snow, 1981). The distribution of modern plant communities might conceivably be identical with past distribution, but it is unwise to assume that this is true, especially considering the extensive changes wrought by modern human activity. It is, however, realistic to assume that because topographic features often condition the distributions of plant and animal species, they are likely to have had a similar relationship to past biotic communities, and therefore, to adaptive strategies. Dancey (1973) has found topographic strata to be the most effective for studies of land use.

Tract classes and microenvironmental strata were initially defined on the basis of knowledge about artifact distribution parameters obtained during reconnaissance surveys conducted in 1966 (for the BLM, Swanson et al., 1969) and again in 1973 as the first stage feasibility study for the present project. Both studies had shown that artifacts and settlements were patterned first according to their proximity to water, and second according to the distance from small stream canyons. The sampling design used in the first phase of intensive survey divided the region into three tract classes and sampled all discernible topographic variability within a sample of each class. Significant topographic features were discerned as a result of this initial effort (Chatters, 1976c) and were used as a basis for microenvironmental stratification used in the final phase of intensive survey (Chatters, 1977).

Seventeen topographic strata were defined on the basis of relief, distance from water sources and relationship to canyon mouths (Table 4). Because they appeared to have been subject to soil creep and recent sheet wash erosion, lands in stratum VII,

Table 4. Definitions of Sampling Strata

Stratum	Definition
I	Flat surfaces greater than 1.50km from canyon mouths in the open plain and less than 50m from and 5m above permanent streams, excluding surfaces subsumed by V.
II	Flat surfaces greater than 1.50km from canyon mouths in the open plain and either between 50m and 150m from permanent streams or less than 50m from and greater than 5m above permanent streams, excluding surfaces subsumed under IVc.
III	Flat surfaces in the open plain which are greater than 150m from permanent streams and greater than 50m from intermittent streams, excluding surfaces subsumed under IVb, IVc.
IV	Surfaces within 10m of terrace escarpments greater than 5m in height and within 10m from and/or on the slopes of terrace escarpments less than 5m in height, all of which are greater than 50m from permanent streams.
A	enclosed in canyons.
B	outside canyons within 1.5km of canyon mouths
C	outside canyons and greater than 1.5km from canyon mouths
V	Surfaces within 10m of the upper edges of escarpments less than 50m from permanent streams in the open plain.
VI	Sloping or level surfaces within 20m of ridge crests, wherever encountered.
VII	Slopes exceeding 5m in height and at an angle greater than 25% (23 degrees).
VIII	Flat surfaces in the open plain within 50m of intermittent streams.
IX	Flat surfaces enclosed in canyons and less than 50m from intermittent streams.
X	Flat surfaces enclosed in canyons and greater than 50m from permanent streams, intermittent streams or springs.
XI	Flat surfaces within 50m of springs.
XII	Morrainal and landslide topography greater than 50m from permanent streams, intermittent streams or springs.
XIII	Flat surfaces less than 50m from permanent streams and enclosed in canyons.
XIV	Flat surfaces less than 1.50km from canyon mouths in the open plain and less than 50m from and 5m above permanent streams.
XV	Flat surfaces less than 1.50km from canyon mouths in the open plain and either 50-150m from permanent streams or under 50m from and over 5m above such streams.

slopes with a grade of greater than 25 percent and higher than 5 m were deleted from analysis. This was the only topographic stratum in which a significant age bias might affect the observation of adaptive patterns for the Holocene period. Stream floodplains attributable to the Holocene were in most cases narrower than 10 m and were readily distinguishable from older deposits on the basis of elevation and particle size. These areas were also left out of the sampling design.

A sample of each tract class was investigated using a non-probabilistic sampling procedure in which narrow, rectangular quadrats were placed such that they crosscut environmental strata and covered each stratum in the tract in approximately equal proportion. The non-probabilistic transect procedure was deemed appropriate for several reasons. First of all, my concern was with distributional relationships between functional classes of artifacts and settlements, and environmental strata, not with network relationships between settlements (cf. Redman, 1973), nor with predicting sizes of artifact or site populations.

Second, sample tracts were non-rectangular. Had each tract been divided into N transects of equal width, as was done by Judge, Egbert and Hitchcock (1975) and by Plog (1976), each transect would have been a different length, reducing the potential that any given point on the land surface would have an equal probability of being searched.

The final, and ultimately most important reason for a non-probabilistic sample is the only one not associated with research or logic: time. Working with a small budget and short field seasons, too much time would have been expended in locating pre-chosen sample units. If those units were square quadrats randomly chosen from each topographic stratum, I could easily have used 30 to 50 percent of field time in locating them. Although randomly chosen transects would have been easier to locate, they too would have proven inordinately expensive.

Finally, non-statistically chosen transect samples are more precise, accurate and efficient than are random transect and square quadrat samples and are equally accurate measures of artifact variability. In addition they are more effective when, as in the case of the Pahsimeroi Valley, the patterns being sampled form a linear array and transects are placed such that they crosscut the grain of the pattern (Judge et al., 1975; Plog, 1976; Hasel, 1938).

For these reasons transect sampling design was appropriate for the Pahsimeroi Valley study. As is true of all other designs, however, the accuracy and representativeness of the data I derived can only be assessed with additional collections from the same area.

Seven tracts were chosen for investigation; three canyons with streams (Tracts C, D, G), three segments of the open alluvial plain, traversed by the Pahsimeroi River (A, E, F) and one canyon with intermittent streams (B). Descriptions of each tract are presented in Table 5, while descriptions of the transects studied in each can be found in two preliminary reports on the project (Chatters, 1976c, 1977). Figure 7 shows the locations of all tracts and the sample units within them.

The placement of transect within each tract was done in the following manner. Stratified maps of tract areas were studied and the landscape was closely observed for locations in which transects might be most advantageously placed for the efficient coverage of topographic strata. This procedure was followed in all but three of the 45 transect placements. Exceptions were made in those cases where low frequency, readily visible features, such as a cabin complex and corral, and the only large artifact aggregate known to exist on the open plain in tracts E and F, had not been covered by arbitrarily placed transects.

During the initial, intensive survey phase of research, 27 sample units were surveyed, varying considerably in size and shape. Most (21) were transect-form quadrats, ranging from 10 m to 50 m in width and from 50 to 4000 m long, oriented perpendicular with stream channels, and crosscutting numerous topographic environments.

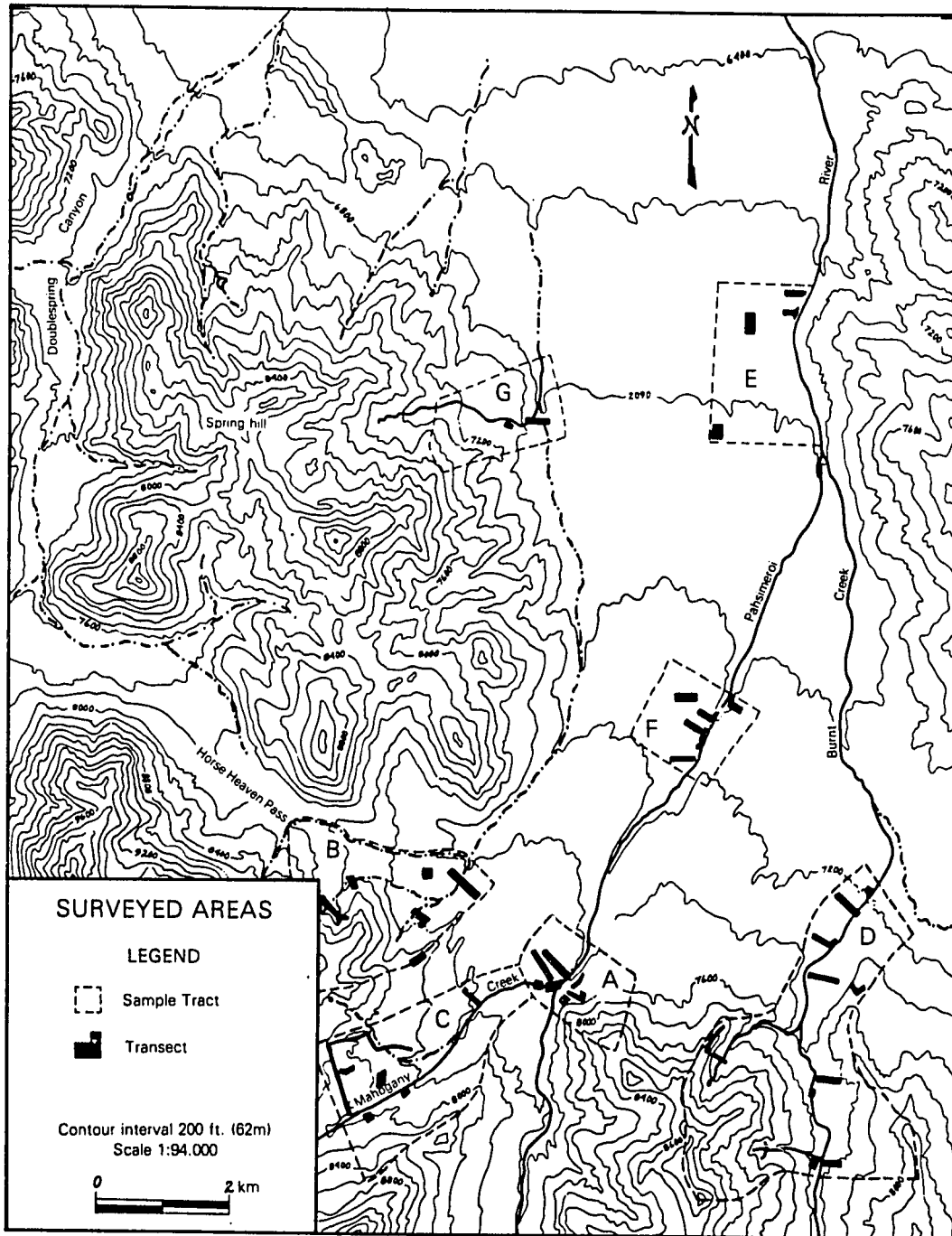


Figure 7. The locations of sample tracts and transects within the study region. Redrawn from USGS Donkey Hills, Doublespring, and Burnt Creek quadrangles.

Table 5. Descriptions of Survey Tracts in the Upper Pahsimeroi Valley Project Area

Tract	Description
A	An open-alluvial-bottom tract located at confluence of Mahogany Creek and Pahsimeroi River where latter stream breaks from its mountain canyon. A sub-rectangular 1.5km x 1.2km area with long axis perpendicular to Pahsimeroi River channel and trending northwest-southeast (see Fig.3). Includes Strata I through VI and Stratum XIII.
B	A canyon-with-intermittent-stream tract that includes southern half of canyon leading from Upper Pahsimeroi Valley to crest of Horse Heaven Pass and all minor draws tributary to that canyon. There is one small spring (Mudspring). Includes Strata III, IVa, IVb, and VI-XI.
C	Basin of Mahogany Creek, a canyon with a permanent stream, from 0.5km above confluence with Pahsimeroi River to arbitrary line drawn 4.0km above same confluence (Figure 3). Includes glacial canyon bounded by steep mountain slopes. Tract surfaces primarily morrainal and alluvial, with permanent and two intermittent streams. Strata: II through X and XII-XIII.
D	Basin of Burnt Creek from Dry Creek Pass road, 2.4km below canyon mouth, to arbitrary line 2.5km above the canyon mouth. Includes broad, alluvial canyon-bottom with permanent stream, two narrow, V-shaped tributary canyons with tiny streams, and the alluvial flat beyond canyon mouth. Strata I through X, XIII, XIV and XV.
E	Segments of open alluvial valley bottom along west bank of Pahsimeroi River. Begins 0.25km below the confluence of Burnt Creek with Pahsimeroi River and continues to arbitrary point 2.5km downstream (northward). Extends west of Pahsimeroi 1.6km into the open plain. Strata I-III, IVb, IVc and VIII.
F	Open-alluvial-flat tract through which flows Pahsimeroi River. This 1.5 square kilometer area parallels river channel beginning 0.93km downstream from confluence of Mahogany Creek and Pahsimeroi River. One third of tract lies southeast of the river, two thirds to the northwest. Strata: same as Tract E
G	Southern half of small canyon formed by massive slide of clays and igneous rock from Spring Hill, including portion of open alluvial plain. Canyon bottom has small, permanent stream, several ponds and meadows in hummocky slide deposits. Strata: III, IVb, IVc, VI, VIII, XII-XV.

The remaining six sample units are in no sense identifiable as transects, having been placed to sample portions of specific topographic features or large, rectangular portions of the open, level alluvial plain (Figure 7; cf. Chatters, 1976c, Figure 7).

Transect shape and size were more uniform during the final survey phase. With the exception of two selectively-placed units, all transects were rectangular in form and extended perpendicular from stream banks to the base or edge of steep slopes (Stratum VII), or were situated in the open plain such that they crosscut topographic strata III and IVc. Except for one transect which ran along a narrow ridge crest, the minimum width of transects was 50 m, with a mean length of 300 m. Sizes actually ranged from 50 m square (in a confined area) to 120 m x 300 m in the open alluvial plain. The 50 m minimum dimension was deemed appropriate since it exceeded the dimension of the majority of aggregates that were encountered (cf. Cowgill, 1975). There were, again, two exceptions: linear aggregates of artifacts which proved to be groups of small, overlapping occupations smaller than 40 m in any dimension; and a large, modern domestic occupation.

Where aggregates were only partially included within transect boundaries, those boundaries were extended to include the entire aggregate. This rule was broken only where aggregates were large (often a kilometer or more in length), linear multi-occupation sites that could not economically be collected in their entirety. Those occurred only in Transects D1 and D4. Figure 8, stratification and transect placement in alluvial plain Tract F, is a typical arrangement.

Sampling Fraction

Seven tracts, comprising 44 transects, were investigated during 1974 and 1975 field seasons. Total tract area was 25.4 million square meters, or 12.4 percent of the project area. Subtracting areas included in topographic Stratum VII, the area enclosed by sample tracts was 15.74 million square meters. Of this area,

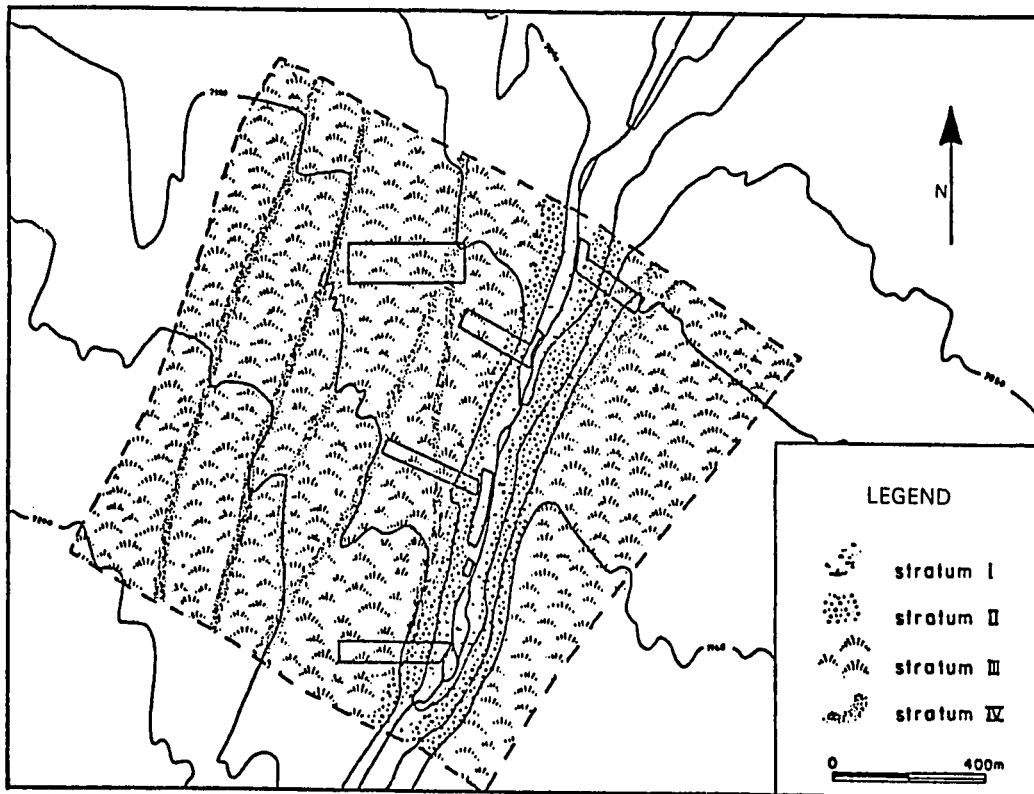


FIGURE 8. Environmental stratification and sampling within an open-alluvial-flat tract, Tract F. Blocked in areas are transects.

Table 6. Survey Coverage Obtained Within Each of the Seven Transects

Tract	Area in square kilometers	Non-Slope Area in square kilometers	Sample Area in square meters	Percent of tract sampled	Percent non-slope area
A	1.75	1.13	118,800	6.8	10.5
B	3.88	2.10	106,255	2.7	5.1
C	4.68	3.45	84,855	1.8	2.5
D	8.75	3.50	103,100	1.2	3.0
E	2.38	2.38	114,500	4.8	4.8
F	1.88	1.88	107,400	5.7	5.7
G	2.12	1.30	17,500	0.8	1.3
Total area of study region: 205.0 square kilometers Total area of sample tracts: 25.44 square kilometers Percent of study region included within tracts: 12.4 percent Total non-slope area of sample tracts: 15.74 square kilometers Total area sampled: 652,280 square meters Mean percent coverage per tract of non-slope area: 4.7 percent					

642,000 square meters, or 4.7 percent, comprised the sampling fraction. The actual percentages of individual tracts (Table 6) ranged from 1.3 percent of Tract G to 10.5 percent of Tract A. G was the only tract sampled at less than 2.5 percent, the result of limited field time for intensive survey during the 1975 season.

The appropriate sampling fraction for archaeological surveys has been a point of some contention (e.g., Mueller, 1974; Mueller, 1975; Schiffer et al., 1978; Cowgill, 1975; Thomas, 1978). Samples have ranged from 1.5 percent (Matson and Lipe, 1975) to 20 percent (Judge et al., 1975) and more. As Cowgill (1964, 1975) and Thomas (1978b) have pointed out, there is no one correct sampling fraction for archaeological studies. It is not the sample's size, but its utility for solving the problem that is important (Cowgill, 1964). In the case of studies of the present type, the goal is redundancy of pattern within all environmental strata (Rice, 1975). As I shall demonstrate in subsequent chapters, redundancy of pattern was achieved for all classes of artifacts and occupations except those which were known at the outset to have been in very low frequencies. The sampling fraction of 4.7 percent (mean) thus proved appropriate.

Data Collection Technique

Transect boundaries were located on the land surface by the placement of cairns or stakes or by using natural features such as trees or abrupt changes in topography (e.g., steep slopes, streams). A map was then drawn of each tract on which topographic features were indicated by estimated contour lines. All maps were made by compass triangulation from sets of datum cairns at a scale of 1:1000. In addition to topographic features, plant communities and the distributions of artifacts and recent faunal remains were marked on these maps. Each transect was tied into the overall referential system of the project by triangulation to bench marks or to the summits of nearby hills. The referential or mapping system consisted of USGS Burnt Creek (1:24,000 scale), Donkey Hills (1:62,500 scale) and Doublespring (1:62,500 scale quadrangles).

Once mapped, transects were thoroughly searched using the well known pedestrian transect technique. Crew members searched each area at a spacing interval of two meters. This high survey intensity (Schiffer and Gummerman, 1977) was necessary because of the need to find and recover a larger proportion of the artifacts in each sample unit, and because low brush and scattered grasses would have reduced artifact visibility if greater spacing intervals had been used. Objects of one square centimeter in size, such as fragments of small projectile points and waste flakes are difficult to spot under any circumstances, and were of critical importance to the research effort (cf. Dancey, 1973; Doelle, 1977).

When artifacts were found, they were marked with flagged metal pins in the manner employed by Dancey (1973) and Davis (1975); dense aggregates of artifacts were tagged only on the peripheries to save time. Marking of artifacts in this manner permitted precise topographic positions to be observed before artifacts were actually collected.

Following Dancey (1973), artifact location was accomplished using three common mapping techniques, with the choice of technique in each instance depending on artifact density. Compass triangulation, an imprecise but relatively fast technique, was used to locate artifacts when density was less than one artifact per eight square meters. Locations of triangulated artifacts were marked on base maps and numbered consecutively for each transect. When artifact densities fell between one per eight meters and one per square meter, the radial offset technique was used. In these cases, secondary datum points were marked on maps of 1:100 scale. Artifact numbering was consecutive for each datum point.

Individual location of artifacts became impractical when densities exceeded one artifact per square meter. Dense aggregates of artifacts were collected by using a datum-based grid system. Grid intervals were one meter for all Native-American artifact aggregates and two meters for a single, large, Euro-American domestic site. The larger grid size was appropriate in the latter case because

artifact patterning within the site appeared to be on a much larger scale than was characteristic of Native-American aggregates. Datum points used in grid and radial offset techniques were tied into the base maps by triangulation to transect corners.

These three mapping techniques enabled the location of artifacts to within one meter of their actual positions (with the above exception). This level of precision facilitated the precise topographic placement of every artifact and permitted the separation of temporally distinct occupations within single artifact aggregates. Once they had been mapped, portable discrete artifacts were collected. Features, non-portable, non-discrete artifacts such as fire hearths, log corrals and irrigation ditches were photographed and mapped at scales of between 1:250 and 1:50 depending on their size.

When wooden features were found, such as log cabins and corrals, sections were cut from construction timbers for use in dating the structures by dendrochronology. Care was taken not to endanger the integrity nor to mar the aesthetic characteristics of such features. Sections also were cut from the stems of big sagebrush (*Artemisia tridentata*) growing in areas that had been enclosed by wooden structures or had recently undergone extensive, anthropogenic soil disturbance (former plowed fields). Patterns of stem growth observed in these sections were used to determine when such areas had last been intensively utilized by people.

In addition to artifact locations, several other categories of data were gathered for each sample unit. Notations were made on the species and approximate numbers of animals living in or having recently traversed the area, and on soil and outcroppings of lithic raw materials.

When faunal remains were encountered, they were identified in the field whenever possible, and recorded. If immediate identification was not possible, bone fragments were collected for later analysis. These data formed the basis for reconstructions of faunal communities of the study area during the past several decades (see Chapter 9).

Finally, to control for biases introduced into the data by variable surface characteristics and by the fieldworkers themselves, the extent of vegetation cover, the apparent age of surfaces, weather and conditions of crew members were recorded regularly.

Summary

Data to be used in the definition of adaptive patterns for the entire span of human occupation in the project area were collected by the siteless survey technique using a multilevel stratified transect sampling design. The project area was divided into tract classes based on large scale topography and a sample of each class was then subdivided into microenvironmental strata. Sample transects 50 m wide and of varying lengths were searched systematically and as many artifacts as could be found were marked, mapped and collected for analysis. This procedure resulted in the intensive investigation of 4.7 percent of the land surface within the tracts chosen for sampling.

CHAPTER FIVE

Adaptive Patterns: Functional Analysis

Nearly 9000 artifacts and the records of their locations comprise the archaeological data acquired from the Upper Pahsimeroi Valley through the survey of 44 sample transects (Table 7). Documentation of changes in human patterns of adaptation from these data required two basic analytical procedures: functional and chronological. Functional analysis formulates the archaeological units: tools and settlements, the environmental distributions of which form land use patterns and settlement patterns, respectively, two components of the adaptive pattern. Chronological analysis established the ages of particular tools and settlements and is the means by which change is discerned in the patterns defined by functional analysis.

Traditions

From the beginning of fieldwork, it has been evident that two distinct artifact traditions (Willey and Phillips, 1958) are represented in the Project Area. One includes sites containing only stone artifacts while the other is comprised almost exclusively of metal, glass, plastic or ceramics. Customarily, North American archaeologists treat these traditions separately, as the prehistoric and historic archaeological records, respectively, and a theoretically and methodologically distinct subdiscipline handles each area. Historical archaeology is most often approached as a means for reconstructing buildings associated with recorded events and acquiring relics of those events for museum display (e.g., Hume, 1969). By contrast, study of the prehistoric record is directed toward an effort not only to reconstruct culture histories and prehistoric ways of life, but also to develop an understanding of the processes of cultural evolution. I eschew this distinction as

artificially obscuring the value of the products of our recent Euro-American ancestors to a scientific study of the archaeological record (as do others: cf. Leone, 1972; South, 1977, 1979 and elsewhere). Therefore, I treat the artifacts of metal, glass and plastic in the same way as artifacts of stone. They are, after all, parts of an archaeological continuum in the Pahsimeroi Valley, as much as part of that record as the Ceramic Fremont Tradition is of Central Utah, where it replaces a tradition comprised largely of lithics (Aikens, 1970; Madsen and Berry, 1975). Consequently, I use the terms Lithic Tradition and Metallic Tradition in reference to the two complexes of artifacts in all subsequent discussions, and conduct the analysis of each using standard archaeological methods.

Table 7. Numbers of Artifacts Recovered from All Sample Units, Divided into Discrete Objects and Features, and Listed by Materials¹

	Material										Total
	Lithic	Metal	Glass	Ceramic	Plastic	Leather	Rubber	Cloth	Wood	Earth	
Discrete Object	7350	991	246	44	14	15	20	2	65		8747
Feature	26						1		5	16	48
Total	7376	991	246	44	14	15	21	2	70	16	8795

¹Roads, fences and biotic artifacts other than wood are excluded from these figures.

Method and Basic ConceptsLand Use and Settlement

The two aspects of the adaptive pattern I am concerned with in the Pahsimeroi Valley are land use pattern and settlement pattern. Land use, the differential utilization of the natural environment, is reflected in the archaeological record as the differential distribution of functionally defined classes of artifact, at any scale with respect to functionally relevant variables in the natural environment (Dancey, 1973:12). This distribution is the land use pattern. Settlement pattern is the differential distribution of settlements, again functionally defined with respect to functionally relevant variables in the environment, either natural or cultural. To the extent that functionally defined classes of settlement can be thought of as functional classes of artifacts at the scale of the aggregate of objects, the distribution of settlement types over the natural environment is in one sense, a subset of the land use pattern (Dancey, 1973). That is, the distribution of settlements reflects the use of some portion of the landscape for some purpose, domestic activity, for example.

In this instance, I retain the distinction between the settlement pattern and the land use pattern. The land use pattern concept is restricted to mean the distribution of tools found outside settlements, as isolated artifacts, and the settlement pattern retains its original meaning. I make this distinction for two reasons, the first analytical, the second related to the meaning of the term land use.

Analytically, the settlement and isolated tool are at different levels. The tool is a discrete entity (see Lithic Tradition: Functional classification, below), whereas the settlement is a model of archaeological entities; some arbitrarily defined concentration of artifacts classified or grouped into types on the basis of the types of tools and features it contains. Consequently, tools, the units in which the land use pattern is observed, are the variables

with which functional types of settlements are defined. Because separate analyses are needed to define these two classes of archaeological unit, it is simpler to divide tool type distributions and settlement type distributions: the result is a less convoluted discourse.

My second reason is the more important. Land use is a concept familiar to most members of our culture, to whom it bears the meaning "the way the land is used." Land use is how we distribute our activities over the landscape (or under it) to acquire commodities for our survival, health or pleasure. It is a complex of individual activities. Although "settlement" itself is a kind of activity, settlements are themselves associations of artifacts which usually represent more than one, perhaps many activities, and the set of activities performed in a settlement may or may not be in any way associated with the acquisition of commodities from the environment (e.g., Binford, 1978a). What I wish to learn from the land use pattern is change in the environmental distribution of activities as represented by individual types of tools. If tools found in settlements, which far and away outnumber those found outside settlements, are included in tabulations, there may be a consistent, perhaps invariable pattern of tool distributions; all may appear to concentrate in the environments where settlements occur, even though those environments may not be the settings from which commodities were acquired. I therefore, have developed a model of land use from isolated artifacts, settlement pattern from concentrations of artifacts, combining the two patterns only in a summary of adaptive patterning (Chapter 7).

The Settlement Concept

The concept of settlement has been in archaeology's lexicon for decades, yet the word has no explicit definition which is adhered to by all members of the profession (Dancey, 1973; cf. Trigger, 1967a; Parsons, 1972). Most authors treat the settlement as a synonym for site (e.g., Parsons, 1972; Struever, 1968a,b, 1971;

Trigger, 1967a,b; Winters, 1969; Willey, 1953; papers in Chang, 1968a and Willey, 1956), but the site concept itself has no universal meaning, usually being tactically defined on the basis of arbitrary, minimum densities of artifacts (Schiffer and Gumerman, 1977; cf. Chatters, 1980a; Plog and Hill, 1971). In other instances, the aggregate, itself a rough equivalent of the site (Dancey, 1973, 1976), and occupation (Dunnell, 1973, Thompson, 1978) have been equated with settlement.

The definition I prefer is that of Chang (1967b). In his words, a settlement is "a unit of prehistoric culture that is in a stationary state and occupies a meaningful area and spans a meaningful microtime" (Chang, 1967b:38). Transforming this idea to the empirical realm, he states that a settlement consists of artifacts and their depositional context, with spatial and temporal dimensions delineating a stationary state (Chang, 1967b:41). This stationary state is to be recognized on the basis of contrast and complementarity exhibited by a set of artifacts.

A settlement may be equivalent to an aggregate of artifacts - a site - but the converse is not always true (Chang, 1967b). This statement definitely applies in the Pahsimeroi Valley. In micro-environmental strata I and XIV, where most artifacts occur, aggregates are often large concentrations extending along stream banks for hundreds of meters. Close inspection of these aggregates revealed that the temporal dimension in no way represented a stationary state. Projectile point styles known from earlier work (Swanson, 1972) to have been made thousands of years apart were often found within a few meters of each other in a continuous scatter of lithics. These aggregates thus were mixtures of assemblages deposited at different times on the same land surface. To have treated them as the units of analysis for defining settlement patterns was inappropriate, and almost certainly would have lead to spurious results.

Chang's concept of settlement is more closely equated with the occupation, an aggregate of artifacts which can be assumed to have

been deposited by a single group of people during a continuous period of time (Dunnell, 1971a, 1973). Spatial continuity establishes that a single group is involved in artifact deposition; complementarity among artifacts in the assemblage and its contrast with other nearby assemblages allows the inference of a continuous period of artifact deposition. That is, if an assemblage exhibits internal complementarity in terms of temporally variable characteristics, such as historic types, kinds of material used in artifact manufacture or in the degree of preservation or weathering among objects, then we can assume that no archaeologically perceptible amount of time elapsed between deposition of the first and last artifacts in the group. Conversely, if an aggregate contrasts with other contiguous aggregates in terms of these same variables, we assume that it was deposited separately, or perhaps by a different group of people.

The settlement as an empirical unit must, therefore (1) be an aggregate or subset thereof, (2) exhibit internal complementarity of temporally variable characteristics, and (3) contrast with other adjacent or contiguous aggregates or portions of the same aggregate in terms of these same characteristics. Because these requirements can only be met through analytical means, the definition of a settlement is dependent on the research problem and the parameters of the archaeological record. I present the procedure used on Pahsimeroi Valley collections in the next section.

Before doing so, however, there is one final aspect of the settlement concept that must be considered. Common English usage attaches an implicit functional meaning to the word, settlement: "a settled place or adobe, a residence" (Webster's New Collegiate Dictionary, 1958). A settlement is a place of residence where the domestic functions of eating and sleeping take place on a regular basis, and meaning of the concept is implicit in the three scales of settlement pattern discussed by archaeologists (Trigger, 1967a; cf. Parsons, 1972). But as it uses the most general form of analogy (Ascher, 1961; Hayden, 1978) to ascribe a function to a particular

archaeological unit, this connotation is inappropriate to evolutionary paleoecology (see Chapter 1). Whether settlements as I have defined them are the site of former domestic activities is irrelevant; only the environmental patterning of functional types of settlement is of concern. Certainly, some types of settlement are probably domestic (Chapter 7) but others may have been more task specific. In any case, to avoid the domestic connotation of the concept, "settlement" will only be used in referring to settlement types; otherwise the less value-laden synonym, "occupation" is used.

Distinguishing occupations (settlements) from isolated artifacts.

An occupation is, first, an aggregate or portion of an aggregate of artifacts, which I define here on the basis of artifact density and proximity (cf. Dancey, 1973). Minimum densities and maximum distances between artifacts are arbitrarily chosen. I consider any four or more artifacts in a density of at least 0.4 artifacts per square meter a useful limit for an aggregate. Any smaller number or lower density and the possibility that the association has occurred by chance is proportionally increased. Once this minimum is met, any artifact within five meters of any member of an aggregate is a part of the aggregate. This latter criterion was violated on one condition: artifacts over five meters away which were made of an unusual lithic material that comprised over 30 percent of an aggregate, were not themselves part of another aggregate and which local topography indicated might possibly have been transported from the aggregate by water action were also included. This exception was made in only three instances.

Those objects not included within aggregates are considered to be isolated artifacts and, by definition are three objects or less with a density of $0.4/m^2$ and $>5m$ from any aggregate or any objects $>5m$ from an aggregate at a density of $<0.4/m^2$.

Once an aggregate had been established, I applied the criteria of complementarity and contrast. For lithic aggregates, I used two variables: projectile point style and lithic material type. During

intensive survey, several aggregates had been discovered which possessed stylistic unity among projectile points. Aggregates A7X, A7Y and D9E, for example, included only small corner notched, large corner notched and small side notched projectile points, respectively. I thus assumed that each represented a single occupation. Further observation revealed that in each case, a few kinds of lithic material comprised the majority of each aggregate and that these abundant materials had nearly coincident distributions in space. Aggregate A7X is a good example (Figure 9). Obsidian and a clear, red and green-mottled chalcedony were the common materials and their distributions were coincident with each other and with the small, corner-notched projectile points (which incidentally were manufactured from the same kinds of stone). Thus, an aggregate or part of an aggregate which contained one projectile point style or a few styles known to be contemporaries (cf. Swanson, 1972) and in which two or more lithic material types exhibited complementary distribution was an occupation. The lithic material criterion alone was used when no projectile points were present.

These criteria were then used to separate large, mixed aggregates into component occupations. In cases where separate occupations overlapped each other, the objects in the overlap zone were removed from further analysis as mixed. If artifacts in this zone exceeded 20 percent of an occupation, the occupation was removed as too incomplete to be used. Members of an aggregate that could be assigned to no occupation were removed as well, since they were neither part of an occupation nor isolated artifacts. This procedure was effective with the large aggregates in transects A1, D4 and G2, but I was unable to discern discrete occupations among the masses of objects in transects B1 and D1.

The result: 49 Lithic Tradition occupations (Table 8) ranging from 4 to 1447 specimens and 4 to 1500 square meters in area.

Metallic Tradition occupations were distinguished by similar means, but the problem of sorting discrete occupations from large, mixed aggregates were simplified by the perishable nature of many

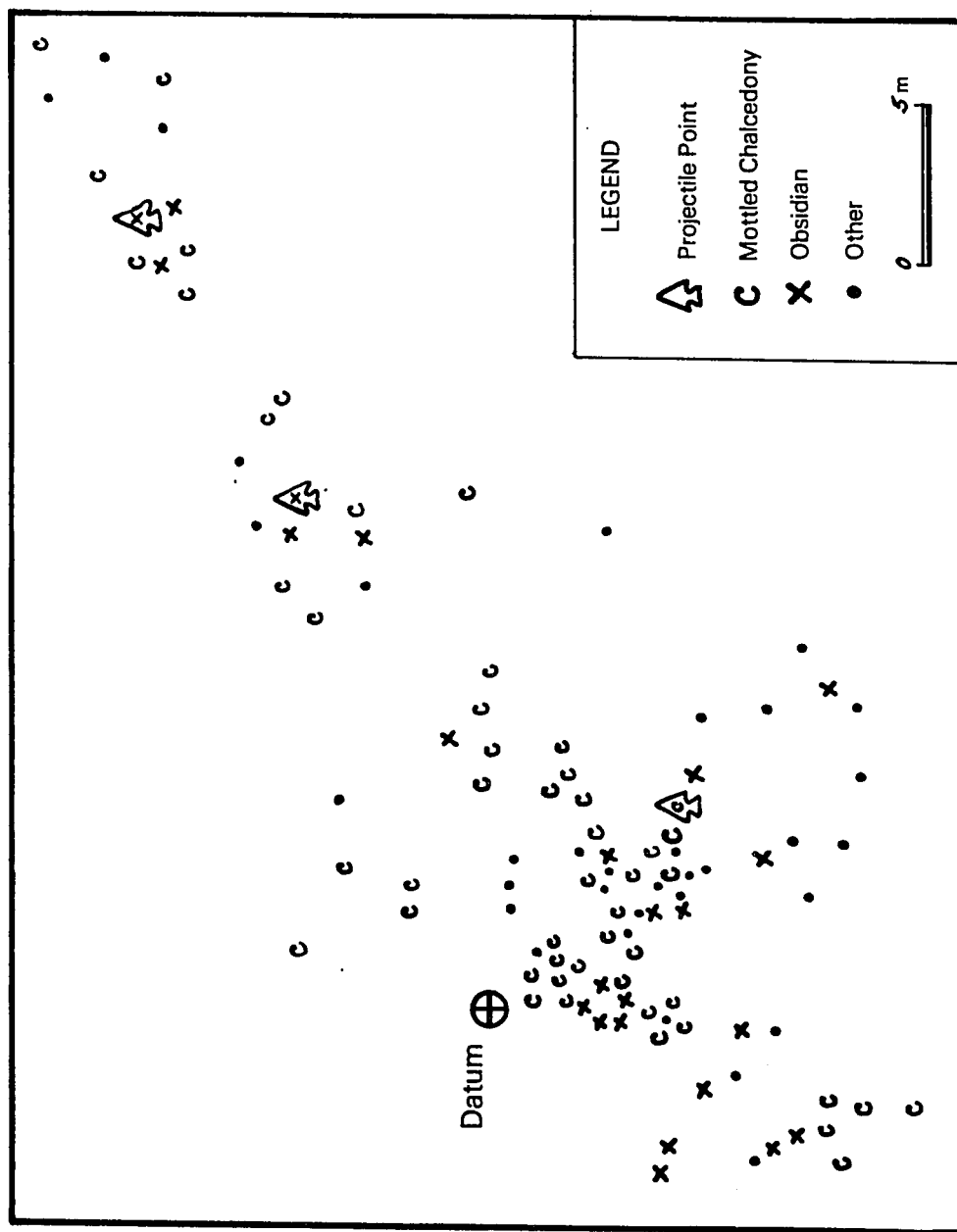


Figure 9. Plan of Occupation A7X, showing coincident distributions of small, corner-notched projectile points and two kinds of lithic material.

Table 8. Lithic and Metallic Tradition Occupations Listed by Sample Tract

Tract	Lithic	Occupations	Metallic
A	A1B, A1C, A1Q, A1U, A1V, A1X, A1Y, A2A, A2B, A3C, A3D, A4M, A7X, A7Y, A8U, A8V, A8X, A8Y, A8Z.		A3E, A4N, A8V, A8W.
B	None		B6P
C	C4A, C5H, C5K		C1A, C1B, C4O, C5J.
D	D1A, D1M, D2A, D2B, D4F, D4G, D4J, D4Q, D4R, D4S, D4Z, D6A, D6B, D7X, D9E, D9F.		D4P, D6A, D8X.
E	E3A, E3B		E1H, E2Y, E3A, E3D, E3E.
F	F2A, F4A		F1Pe, F1P1, F1C, F2Be, F2B1, F4B.
G	G1L, G2A, G2B, G2C, G2D, G2F, G2G.		
Total	49		23

associated materials and by my own participation in the culture they represent. In this case, the temporally meaningful variables were differential preservation of steel, glass and organics and the presence or absence of manufacturing techniques (soldering vs. crimping of cylindrical cans; cf. Hunt, 1959), or materials (plastic, aluminum) known to have been in use only for a limited period of time.

The most complex example from this tradition was aggregate F1P, a dense concentration of cans, metal, glass and other artifacts clustered about a complex of log buildings. The place had clearly been used on at least two widely separated occasions, represented by heavily rusted steel versus nearly rust-free steel, aluminum and plastic. There was no steel in an intermediate condition. Distribution maps (Figure 10) revealed that early and late occupations had not been coterminous. Most unrested steel, aluminum and plastic - the late occupation - lay south of the largest building, while rusted steel was concentrated to the west and north. Both periods were represented about equally on the building's east side and in a small area surrounding the smaller building.

Thus, for analytical purposes, the artifacts found in the mixed areas were discarded. To further reduce the effects of mixing, corroded artifacts found in the "late" area and unrested, aluminum or plastic items found in the "early" zone were also removed from consideration.

Metallic Tradition occupations number 23. Although they include from 4 to 582 artifacts, only three occupations contained more than 40.

Functional Analysis

Studies of land use and settlement patterns require the observation of differential distributions of functionally relevant cultural variables over the natural environment. Land use, as defined above, is concerned with isolated functional variables at the scale of discrete objects and features, while settlement pattern is based

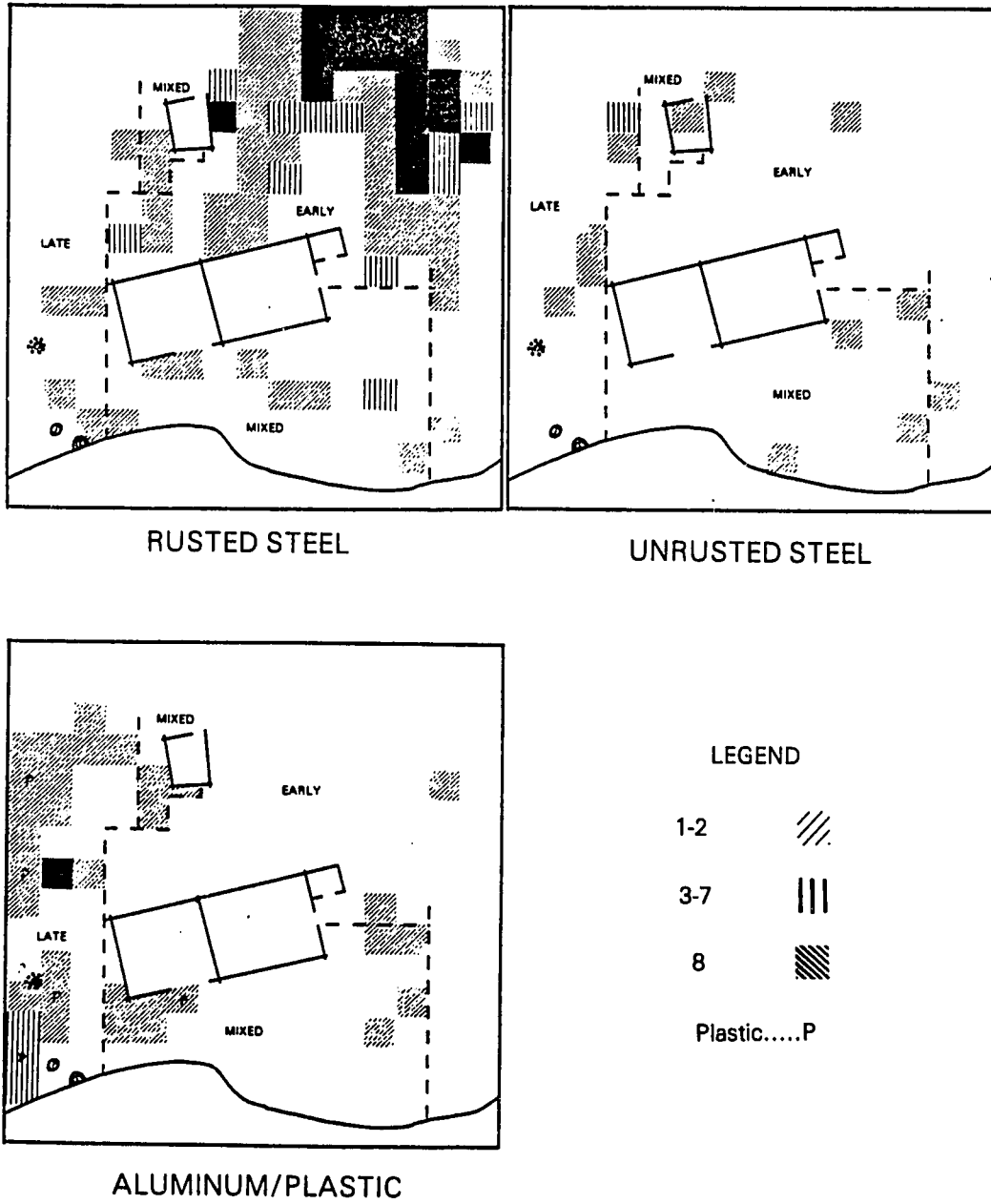


Figure 10. Plan of Transect F1, showing the distributions and densities of historically meaningful artifact classes.

on the aggregate scale. This difference is only superficial in the sense that settlement types are usually defined on the basis of quantitative, qualitative and spatial relationships between functional classes of artifacts found within the aggregate (Struever, 1968b; cf. Dancey, 1973; Fitting, 1969; Rice, 1975; Winters, 1969; Willey, 1953; cf. Price, 1978). Therefore, the functional classification of artifacts at the discrete object and feature scales is the foundation of the present analysis.

Two approaches to the question of artifact function are extant. One approach is based on the premise that archaeological data are incomplete ethnographic data and that it is the business of archaeologists to reconstruct prehistoric cultural systems to the fullest possible extent (e.g., Binford, 1968a; Fritz and Plog, 1970; Hill, 1966; Longacre, 1964; papers in Redman et al., 1978; Watson et al., 1971). Toward this end, archaeologists rely heavily on reasoning by analogy between artifacts used by living or ethnographically described peoples and the objects found in archaeological contexts (Asher, 1961; Chang, 1967; Binford, 1967; Hayden, 1978). When similar forms of artifacts or artifact associations are observed in prehistoric and ethnographic contexts, it is usually concluded that the prehistoric and modern objects had the same function. Some authors require a higher degree of formal similarity between ethnographic and archaeological materials (e.g., Binford, 1967), but the overall approach is the same.

Based as it is on the invalid concept of substantive uniformitarianism (Gould, 1965; cf. Slotkin, 1952) as expressed in the assumption that form, function and the relationship between them are identical through time, analogy is inappropriate to the evolutionary paleoecological approach.

A second approach to function rejects the notion that the archaeological record is an incomplete, yet reconstructible ethnographic record and instead treats artifacts as an independent body of data, the behavior of which is explicable in its own terms (Dunnell, 1971; 1978b). Proponents of this second approach contend

that it is not always possible to know what activities are represented by artifacts (cf. Binford, 1964 in another context) nor is it necessarily desirable to do so. When the goal is to observe patterns of human habitation, as it is here, the recognition that differences exist between the kinds of activities performed in distinct environments is sufficient (cf. Thompson, 1978). When time is added to the equation, changes in adaptive patterns, their evolution, can be observed and, through identification of the time and resource portions of the ecological niche and analysis of the relationships between these variables and environmental conditions, explained. All this can be completed without recourse to analogy. True, behavioral interpretations can be accorded the results of such an analysis, but they do not enter into the construction of functional units nor to achievement of the results.

From this second viewpoint, artifact function is not equated with ethnographic use, but is strictly an archaeological concept. Functional variables are those which directly affect the Darwinian fitness of the populations in which they occur (Dunnell, 1978a), and prehistoric function is defined as the artificial relationship between an object and its natural and/or artificial environment (Dunnell, 1971a, 1978b). In the empirical realm, then, a functional variable is recognized as a characteristic that exhibits a non-random distribution with regard to the environment (i.e., bears an observable relationship to environmental variables). Functional classes of artifacts are defined on the basis of such functional variables and may in turn be the criteria on which functional classes of settlements are defined.

Because it does not employ unsound uniformitarian assumptions, this approach is more parsimonious than the first, and is thus better for generating explanations of evolutionary process. With its rejection of the premise that past and present are the same, and its explicit relationship to the concept of Darwinian fitness, the scientific model is appropriate to the evolutionary paleoecological paradigm. It is this approach to function that I use here.

Functional classifications. In the following pages, I develop functional classifications at three scales: discrete object, feature and occupation. Functional classes at the two smaller scales will be paradigmatic, defined by intersection of attribute sets called dimensions (Dunnell, 1971b; Spaulding, 1953). Settlement types, functional units at the occupation scale, will be defined using grouping procedures of numerical taxonomy (cf. Sokal and Sneath, 1963) with functional classes of artifacts as the variables whose quantitative representation is the basis for grouping.

The model of function I employ specifies that if classes are functional, they should exhibit differential environmental distributions, the functional nature of a particular classification can thus be tested. A classification is initially formulated on the basis of attribute dimensions believed to be functionally meaningful and the environmental distribution of class denotata are then inspected for patterning. If patterning exists, the classification is usable for observing adaptive patterns; if randomness prevails, the classification must be reformulated.

In this case, I devise classes of discrete objects and demonstrate their functional character in the prescribed manner. I then create settlement types using classes at the discrete object scale as variables. Because the variables used in their creation are known to be functional, I thus assume, without further testing, that settlement types have functional meaning as well.

Details of each analysis appear below. Lithic Tradition artifacts and occupations are considered first, followed by Metallic Tradition assemblages.

Lithic Tradition

Discrete Objects

The functional classification I use here is based on wear-related attributes of stone artifacts. Rationale for that choice and the techniques I used in its application follow.

Wear as a functional variable. The cultural variable most readily ascribed to function is wear (cf. Dunnell, 1971a, 1978b; Keeley, 1974, 1980; Odell, 1975; Odell and Odell-Vereecken, 1980; Semenov, 1964 and others listed below), which is the set of attributes which result from friction caused by an artifact's artificial motion through another medium. The functional meaning of wear is demonstrable empirically.

Empirical support for the equation of wear with use and, therefore, function, comes from the extensive studies of microscopic wear patterns in lithic artifacts. Although these studies were initiated and are pursued with the explicit purpose of reconstructing tool function through the use of analogy between the experimentors' actions and prehistoric uses of tools (cf. Gould et al., 1971; Keeley, 1974; Odell, 1975; Tringham et al., 1974; Semenov, 1964) they have provided valuable data on the mechanical processes of wear pattern production. The physics of stone fracture (Crabtree, 1972; Cottrell and Kamminga, 1979; Tsirk, 1979; Faulkner, 1972; Speth, 1972) and the formation of striations (Lawn and Marshall, 1979) and polish (Del Bene, 1979; Kamminga, 1979) have been carefully studied and their relationship to tool use has been demonstrated (Keeley, 1980; Lawrence, 1979; Newcomer and Keeley, 1979; Odell and Odell-Vereecken, 1980).

Lithic wear pattern analyses have conclusively proven that different uses of stone tools produce different attributes of wear. The direction and intensity of force, the angle at which the tool is held and the hardness and chemical makeup of the medium being worked all condition the shape, orientation and intensity of tool wear. Unfortunately, the same mechanical processes that result in tool wear, when controlled, are used to produce stone tools and it is often impossible to distinguish between technologically produced attributes and wear (Dunnell, 1978b; cf. Hayden, 1979:360-70; Sheets, 1973). To further complicate matters, striations, polish and chipping can develop on stone tools as a result of trampling by cattle (Knudson, 1979) and geologic processes of erosion, to name

but a few (cf. discussion in Hayden, 1979:367-371). Although they appear at first to be severely detrimental to analyses of artifact wear for functional classification, these sources of wear-like attributes should display distinctive distributions (Dunnell, 1978b) and constitute greater or lesser background noise.

One further complicating factor exists which compromises the analyst's ability to compare two or more assemblages on the basis of lithic use-wear. That factor is a form of allomorphic variation related to characteristics of the lithic material itself and mitigates against the equality of wear patterns on tools used for exactly identical purposes. Because different materials may react variously to the same stresses due to variations in hardness or crystal size and structure, the wear characteristics also vary (cf. Grieser and Sheets, 1979; Odell and Odell-Vereecken, 1980). This problem is insoluble, and is a primary reason why the grouping of occupations into settlement types is expected to produce sets whose members exhibit less than equivalent frequencies among various functional classes.

Techniques of observation. Most studies of lithic use-wear employ varying powers of magnification to observe attributes such as small scale striations and fine hertzian fractures. High magnification is advocated by some authors (cf. Keeley, 1974; Keeley and Newcomer, 1979; Semenov, 1964), although most proceed with low power magnification (cf. Odell, 1975; Odell and Odell-Vereecken, 1980; Tringham et al., 1974; Wylie, 1975). Still others observe wear macroscopically (Aikens and Minor, 1976; Dancey, 1975; Dunnell et al., 1973; cf. Dunnell, 1971, 1978b) or at a maximum magnification of 10x (Rice, 1975).

I have chosen the macroscopic approach for two reasons. The foremost consideration was time. Most microscopic analyses of lithic use-wear have been either experimental (cf. Keeley and Newcomer, 1977; Tringham et al., 1974) or have been undertaken to determine the use of macroscopically defined classes of tools

(cf. Wylie, 1975) and therefore addressed only a small number of objects. These analyses have been expensive in terms of time. Wylie (1975) estimates that 20 minutes were required to study each of his 1000 Hogup Cave specimens; high power studies would be even more time consuming. Using Wylie's 20 minute estimate, approximately 2300 hours or nearly 300 work days would have been expended in the low power (40-100x) analysis of Pahsimeroi Valley collections.

The second reason is natural abrasion. Surface artifacts are exposed to erosion by wind-blown particles of quartz, which produces microscopic striations over large areas of the artifact surface. Although these marks are said to be randomly distributed (Gibson, 1979:367-8), it is possible their presence would obscure microscopic use-caused striations and polish.

Therefore, because of the exorbitant amount of time required for their application and the dubious value of the potential results, I chose not to use either of the microscopic approaches, preferring the less precise, but more economical macroscopic observation of lithic use-wear.

Functional classification. Wear-related dimensions initially used in the classification of Pahsimeroi Valley lithic artifacts were: kind of wear, location of wear, the shape of the worn edge or area, angle of wear, faciality of wear and length or area of wear (Table 9). Dimensions of edge angle and length or area of wear were dropped from the final classification. Edge angle immediately showed a strong tendency to correlate with classes formed by the intersection of faciality and kind of wear (confirming results of Wilmsen, 1968, 1970; Wylie, 1975) and was redundant. The length or area dimension exhibited no tendency toward statistical multimodality and could not be separated into discrete attributes. The final classification therefore comprised four dimensions and 205 possible classes.

Table 9. Functional Classification Used in Analysis of Lithic Artifacts*

Dimension	Attribute name	Attribute definition
Kind of wear	Z. chipping	Three or more hertzian cones within less than 5mm of one another, less than 30% of which have hinge or step terminations.
	C. hinge/step	Three or more hertzian cones within less than 5mm of each other, more than 30% of which have hinge or step terminations.
	D. abrasion	Three or more parallel striations less than 1mm apart and greater than 4mm long.
	P. polish	A high sheen confined to only a portion of an object. Sheen on all artifact edges or an entire surface is considered to be a natural condition.
	F. crushed	Small, irregular fragments removed over 5mm of edge or 1 square cm of surface or more.
	G. chipping and polish	Combination of Z and P.
	H. chipping and abrasion	Combination of Z and D.
	L. hinge/step and polish	Combination of C and P.
	M. hinge/step and abrasion	Combination of C and D.
	N. abraded and polished	Combination of P and D.
Location of wear	O. No wear	
	E. surface	wear on one plane only.

Table 9. (continued)

Dimension	Attribute name	Attribute definition
Location of wear	O. edge	Wear on the intersection of two planes.
	I. point	Wear on intersection of three or more planes, continuing onto adjacent edges.
	J. None	
Shape of worn area	T. concave	Indentation of edge or surface with a width greater than twice the depth.
	X. notch/pit	Indentation of edge or surface with width less than twice the depth.
	V. convex	Edge or surface inscribes arc of zero or more degrees (ie., includes flat surface and straight line.
	Z. None	
Faciality	U. unifacial	Wear on one surface or one side of edge only.
	Y. bifacial	Wear is coincident on two sides of edge or two opposing surfaces.
	E. alternate	Wear is on alternate sides of parallel or intersecting edges.
	F. None	
Angle		Angle created by wear attributes measured to the nearest 5.0 degrees.
Length or area		Size of worn area or length of worn edge measured to nearest 2mm (length) or 0.5 square cm (area).

*Terminology follows Hayden (1979).

Clearly, intersections of the four functional dimensions could occur more than once on any given object, and in fact they often do (cf. Dancey, 1973). Therefore, the unit being defined in this classification is not the object but a phenomenon smaller than the object, called the tool. A tool is defined here as "the maximally concurring set of functional attributes associated within the confines of a single object" (Dennell, 1978b).

When this classification was applied to the lithic artifacts from surface collections, 1022 tools were identified, distributed over only 19 tool classes (Table 10). An additional 3199 objects were unworn.

As Table 10 shows, I have added a 20th tool function class, created by subdividing the unworn class on the basis of overall shape. This new class consists of projectile points and fragments thereof and the decision to include it in the list of tools is based on extensive observation of the archaeological record. Projectile points, as defined in Table 10 commonly occur in environmental settings where other unworn lithics are rare or absent. For example, they occur embedded in the bones of human beings and other animals, attached to arrow and dart shafts and as isolated finds far from any settlement or lithic material source. Other unworn lithics - usually flakes or chunks of raw material, rarely if ever are found in these settings. Consequently it is reasonable to conclude that the two classes of unworn objects are functionally distinct; hence the 20th class.

The number of classes used to study settlement and land use patterns had to be reduced from the original 21 (including projectile points and other unworn objects). Because of the paucity of isolated finds in most microenvironments and the small size of many occupations, sampling error was a severe problem. With 21 tool classes and samples of tools often that size or smaller, sampling error could have been a more important variable in determining frequency distributions of functional classes than were the kinds of activities that produced the artifacts. I therefore

Table 10. Tool Types Used in Settlement and Land Use Pattern Analysis for the Lithic Tradition

Type	Class	N	Definition
0	-----	3069	unworn (other than Type 13)
1	ZOVY	373	bifacial chipping wear on convex edge
2	COVY	21	bifacial hinge/step wear on convex edge
3	ZOVU	214	unifacial chipping wear on convex edge
4	COVU	193	unifacial hinge/step wear on convex edge
5	ZOTU	49	unifacial chipping wear on concave edge
6	COTU	77	unifacial hinge/step wear on concave edge
7	ZOTY	16	bifacial chipping wear on concave edge
8	ZIVU	20	unifacial chipping wear on a point
	CIVU	15	unifacial hinge/step wear on a point
9	CIVE	8	alternating hinge/step wear on a point
10	ZIVY	7	bifacial chipping wear on a point
	CIVY	2	bifacial hinge/step wear on a point
11	LOVU	14	unifacial hinge/step and polish on a convex edge
12	LOTY	2	bifacial hinge/step and polish on a concave edge
	COTY	1	bifacial hinge/step wear on a concave edge
	DETU	1	abrasion on a single, concave surface
	GOVY	1	bifacial chipping and polish wear on a concave edge
	POVU	1	unifacial polish on a concave edge
	LOVY	1	bifacial hinge/step and polish on a convex edge
13 projectile point		130	unworn trianguloid or leaf-shaped bifacially-flaked object with blade and hafting device; or a fragment thereof.

compressed the 21 tool classes into 14 types by taking two steps. First, I combined chipping wear with hinge-step chipping wear for all tools with wear on a point, and second, collapsed all remaining classes with two members or less into an "other" category.

The reasoning behind collapsing wear dimensions for point tools only were these:

1. They were, besides the "other" group, the least common classes and their presence or absence was, therefore, more likely to vary with sample size than it would for more populous categories.
2. Unifacial wear on a point is produced by drawing a pointed object in a single direction; bifacial wear, by drawing in two directions alternately or by penetrating a surface and twisting back and forth.

The new set of types reflects these differences, but combines two kinds of concoidal fracture wear, chipped vs. hinged or stepped wear, the difference between which is in the amount of force exerted or the hardness of the material being shaped. Thus, the new combination retains the broad distinction between kinds of artifacts producing a tool, but eliminates some detail. Had I combined attributes in any other dimension, such as shape of worn area, more distinct activities might have been joined and a greater degree of precision lost to the studies of patterning.

Testing the functional types. If they are indeed functional, tool types should display nonrandom environmental distributions (Dunnell, 1971a, 1978b; Thompson, 1978). Table 11 lists the distributions of functional types over all microenvironmental strata for which lithics were analyzed. Although sample sizes are small, a high degree of patterning is evident, especially among the five most common tool types (Figure 11). For example, Type 6 is in its highest proportion in Stratum VI while for Type 13, it is IVb and IVc. No type is evenly distributed with respect to environment, and the functional character of the classification is not falsified.

Table 11. Microenvironmental Distributions of Lithic Tradition Functional Types,
Presented Both as Raw Frequency and as Percentages of Types 1 through 13*

Stratum	Functional Type													Total 1-13
	1 N%	2 N%	3 N%	4 N%	5 N%	6 N%	7 N%	8 N%	9 N%	10 N%	11 N%	12 N%	13 N%	0 N%
I	7 (6)	3 (6)	8 (16)	18 (32)		1 (2)	1 (2)	4 (8)	1 (2)		1 (2)		7 (14)	50
III	1 (50)												1 (50)	1
IVb	12 (25)	1 (2)	5 (10)	13 (26)		1 (2)	1 (2)						13 (26)	14
IVc	2 (10)			3 (18)	1 (5)	1 (5)							13 (65)	3
V	1 (17)					1 (17)							4 (66)	
VI	3 (20)	1 (7)	2 (14)	4 (27)		3 (20)		1 (7)		1 (7)			1 (7)	17
VIII	1 (25)		1 (25)	1 (25)									1 (25)	
XIII	13 (27)		15 (32)	6 (12)	1 (2)	3 (6)					2 (4)		7 (15)	185
XIV	324 (24)	16 (2)	178 (19)	147 (16)	47 (5)	66 (7)	14 (2)	29 (3)	7 (1)	8 (1)	11 (1)	6 (1)	82 (9)	2678
XV	9 (38)	1 (4)	7 (29)	3 (12)		1 (4)		1 (4)					2 (8)	121

*Only those strata that actually contained lithics are shown.

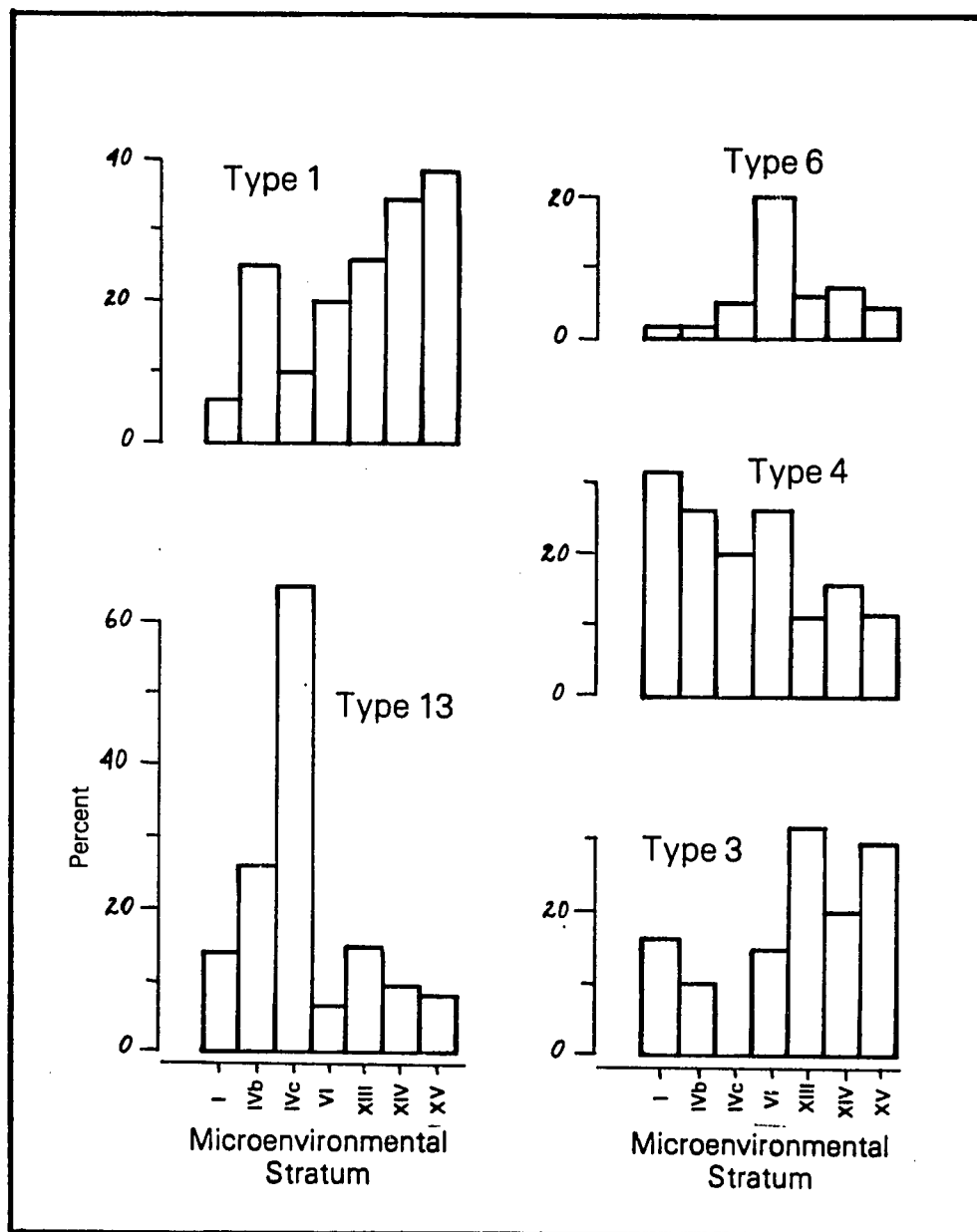


Figure 11. Microenvironmental distributions of the five most common Lithic Tradition functional types. Percentages denote the proportion of each type among all tools found in a microenvironment. Only the seven microenvironments with 15 or more tools are included to avoid the problem of small sample sizes.

Features

There were only 16 features that can certainly be attributed to the Lithic Tradition. Seven of these are small pits under 1 m in diameter, all of which show extensive infilling and have become revegetated; the rest are lichen-encrusted rings of stone 4 - 5 m in diameter (5) and cairns (4). All three kinds of features have restricted distributions - pits are all in Stratum VI, circles in Stratum XIV, and cairns are either on ridges or the upper edges of terrace escarpments, so all three kinds of features are functional.

Occupations

Occupations were formed into settlement types on the basis of tool types 1 to 13 (using numerical taxonomic methods), and settlement area. Before creating settlement types from the area's 48 occupations, I first divided occupations into three groups, based on the total number of tools. The purpose of this move was to minimize the effects of sampling error on the multivariate grouping procedures applied to the two larger groups. Group 1 consists of occupations with 26 or more tools, or at least twice the number of tool types to be used as variables. Group 2 occupations have 13 to 25 tools, or from one to two times the number of types, and Group 3 comprises all remaining occupations.

Groups 1 and 2, a total of 18 occupations, were analyzed by numerical taxonomic methods (cf. Sokal and Sneath, 1963; Sneath and Sokal, 1973). The procedure used for Group 3 is best called impressionistic, with occupations placed with others to which they appeared to be most similar.

Groups 1 and 2: Numerical taxonomy. Numerical taxonomic methods generally fall into two categories; clustering and ordination (Sneath and Sokal, 1973). Both are used to group units on the basis of similarities between units measured along multiple variable dimensions. Clustering algorithms create groups directly by iteratively linking together those units or groups with the highest

shared similarities. Ordination methods, on the other hand, attempt to order units in hyperspace such that the distance of each unit from each other unit reflects its dissimilarity from that unit. The results of ordination procedures are displayed as two or three dimensional plots of points representing analysis units. Whereas clustering algorithms provide the analyst with statistically defined groups, ordination procedures require the analyst to discern groups from among the plotted data points by visual inspection. Such arbitrary visual clustering is difficult to support and to replicate (Sneath and Sokal, 1973), and is therefore a less than optimal approach to grouping.

I have chosen to use clustering to initially create groupings of occupations in Groups 1 and 2 and to corroborate those results using ordination.

Numerical taxonomy has been increasingly used in archaeology in the late 1960's and 1970's for classification of discrete objects (Clarke, 1968; Doran and Hodson, 1975; Englebrecht, 1974; Hodson, 1970; Hodson et al., 1966; Solomon, 1971), studies of stylistic distributions over space (e.g., Frankel, 1974; Rowlett and Pollnac, 1971; cf. Matson, 1980), settlement type definition (Pokotylo, 1978; Thompson, 1978) and for seriation (Johnson, 1972; Matson and Lipe, 1979; cf. Cowgill, 1968). A variety of clustering algorithms have been applied to taxonomic problems, the more common among them being single linkage, double linkage, complete linkage, average linkage or the pair group method, and various centroid methods including K means. The choice of which algorithm to apply to a given problem depends on three factors: (1) the theoretical soundness of the method, (2) its suitability to the present problem, and (3) its practical feasibility (Hodson, 1970; Johnson, 1972).

To define settlement types from the Group 1 and 2 Lithic Tradition occupations, I chose to use the unweighted average linkage method (Sokal and Sneath, 1963). Average linkage, although not the mathematicians' choice, is theoretically sound and avoids the unit chaining of single linkage (Doran and Hodson, 1975; Hodson, 1970; Hodson et al., 1966; Sneath and Sokal, 1973) and the ambiguity of

double linkage and centroid methods (Hodson, 1970; Sneath and Sokal, 1973). In addition, average linkage clustering produces results with the highest degree of cophenetic correlation, meaning it is the clustering method that reproduces the relationship between units most accurately (Boyce, 1969; Sokal, 1969). Finally, average linkage clustering can be done fairly quickly by hand on less than 20 units (Cowgill, 1968). The only drawbacks to the method are that slight differences in the way original data are scaled or in the way similarity is calculated may have major effects on the resulting clusters. In addition, units can easily be trapped into clusters, from which they cannot escape (Hodson, 1970). These problems are true of most heirarchic, non-overlapping clustering methods and must be accepted as inherent weaknesses to be taken into consideration when clusters are interpreted.

Average linkage is a sequential, agglomerative, hierarchic non-overlapping method. Once one has calculated a matrix of similarity values, the matrix is scanned for the pair of units with the highest similarity value. These units are grouped and the matrix is then searched for the pair with the next highest similarity or the unit with the highest average similarity with the first group. Each unit or group is then combined with the unit or group with which it has the highest mean similarity. This procedure is repeated until unity has been achieved (cf. Sokal and Sneath, 1963). Results are displayed on a dendrogram and the analyst delimits clusters by drawing an arbitrary line across at a given similarity level. The separate branches below that line are the groups with which he will work.

Average linkage clustering was first performed separately on Group 1 and 2 occupations, using the Brainerd-Robinson Coefficient of Agreement (Robinson, 1951; Brainerd, 1951), calculated by comparison of the distribution of 13 functional types in each occupation. Basic data from which the Brainerd-Robinson Coefficients were calculated, along with additional information about each occupation is presented in Tables 12 and 13. Figures 12 and 13 show the results of these analyses.

Table 12. Basic Data on Occupations in Group 1, with 26 or More Units in Functional Types 1-13

Occupation Stratum	1	2	3	4	5	Functional Types					9	10	11	12	13 (1-13)	Total Type 0	N objects	Area in sq. m.
						6	7	8										
D4Q XIV	59	1	41	24	8	8	1	1	1	1	3	1	18	186	1027	1172	850	
A1Q XIV	31	2	24	17	5	10	1	4	1	3	0	0	6	104	1015	?	780	
D4S XIV	62	1	6	19	3	7	1	4	1	2	1	1	6	114	267	353	1500	
D4R XIV	29	1	8	16	5	6	0	1	0	1	3	2	2	73	150	181	400	
A1C XIV	14	1	13	10	1	8	1	4	0	0	1	0	11	64	119	165	1150	
D4Z XIV	24	0	13	11	2	1	0	2	1	0	0	0	2	56	102	139	800	
A1Y XIV	12	2	17	8	6	1	2	0	0	0	0	0	4	53	125	171	1010	
A1V XIV	7	0	7	8	0	10	0	4	1	0	1	0	4	42	44	75	600	
A7X XIV	11	0	8	5	5	1	2	0	0	1	0	0	3	36	88	122	900	
A1B XIV	12	2	6	3	1	2	1	0	0	0	0	0	1	28	71	91	1020	

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Table 13. Basic Data on Occupations in Group 2, with 13-25 Units in Types 1-13

Occupation Stratum	1	2	3	4	5	6	7	8	9	10	11	12	Total Type		N objects	Area in sq. m.	
													13 (1-13)	0			
D4J XIV	11	1	7	3	0	0	0	0	0	0	0	0	1	23	63	84	450
A74 XIV	5	2	2	4	2	3	0	0	0	0	0	0	4	22	17	37	600
A2A XIV	2	2	4	7	0	0	0	0	1	0	0	1	5	22	75	93	140
D9E XIII	8	0	7	1	1	1	0	0	0	0	0	0	2	20	146	166	170
G2G XIV	8	0	4	2	0	0	1	0	0	0	0	0	2	17	177	194	200
G2F XIV	5	1	3	1	2	0	1	0	0	0	0	2	1	16	184	200*	150
F4A V	4	0	2	9	0	1	1	0	0	0	0	0	0	17	18	33	600
A1U XIV	5	0	3	3	2	0	1	0	0	1	0	0	2	17	15	29	600

* this occupation also included 15 fragments of ceramic not in this count.

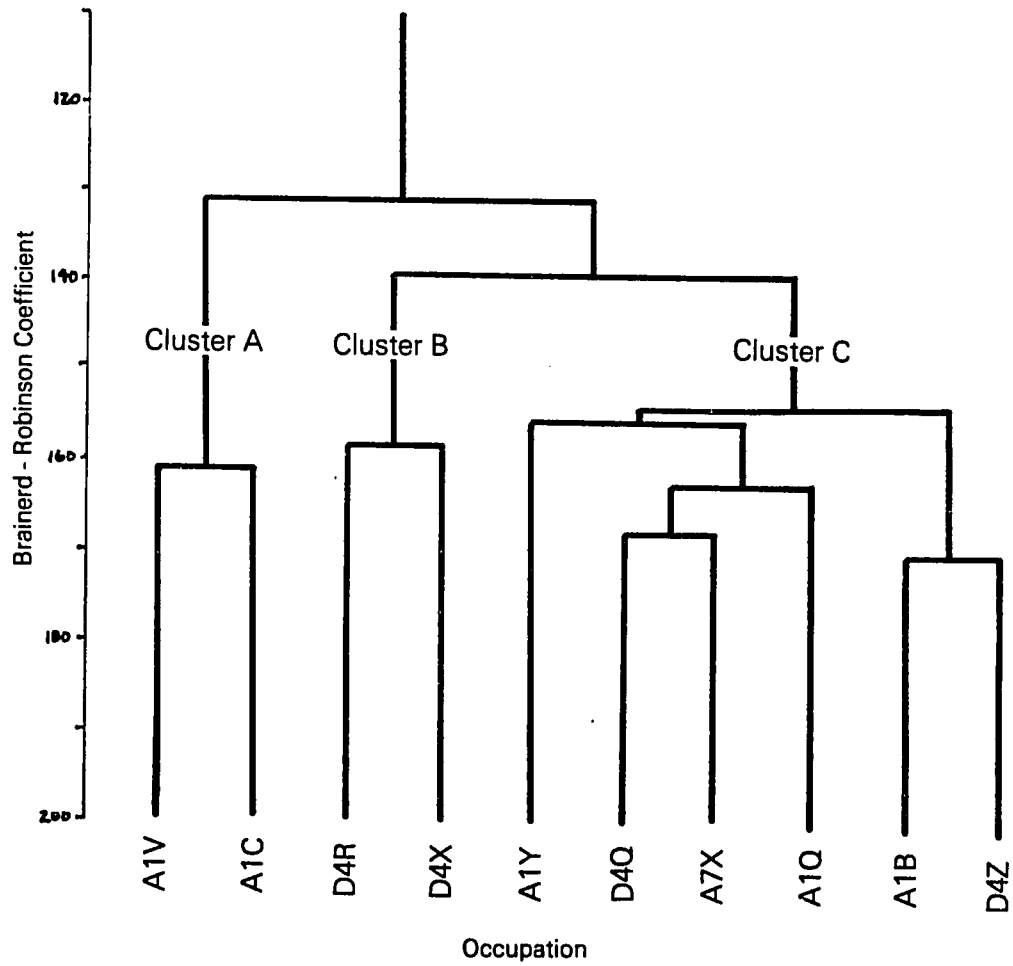


Figure 12. Average linkage clustering dendrogram for occupations in Group 1.

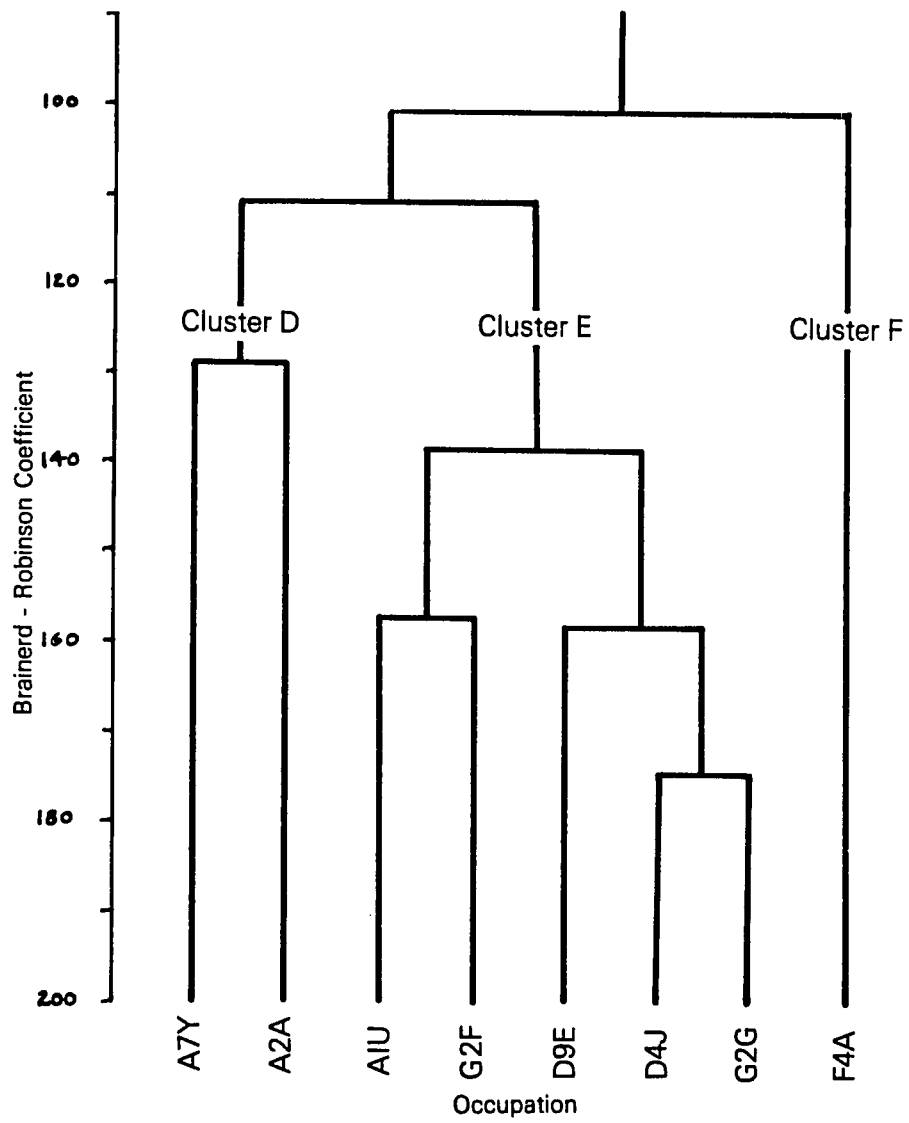


Figure 13. Average linkage clustering dendrogram for occupations in Group 2.

The similarity level chosen for clustering in Group 1 was 150; 125 was the figure used for Group 2. I chose disparate similarity levels according to the degree to which I believe sample size to have affected the clustering procedure. Because Group 2 samples are small and because Brainerd-Robinson Coefficients are based on percentages, the similarity coefficients calculated for this group fluctuated more widely than they did for Group 1.

Three clusters are distinguished in each occupation group; clusters A, B and C in Group 1, D through F in Group 2 (Figures 12 and 13). To compare these two sets of clusters and to create a single set of settlement types, I first calculated similarities between occupations in Group 2 and the three clusters formed in Group 1 (Table 14). All occupations from Cluster E were most similar to Cluster C, while members of Clusters D and F showed no strong similarity to any other group. Clusters C and E were thus provisionally combined into a single cluster G, leaving a total of five clusters.

To see if this provisional grouping would stand if all members of Groups 1 and 2 were analyzed together, a third cluster analysis was performed on the full 18 x 18 unit matrix (Figure 14). The result is positive, although the five clusters are not distinct at a single level of similarity. At the 125 level, there are three clusters, with A, B and G combined into one; at the 140 level, there are three isolated units. Nevertheless, I have retained the five cluster grouping system. Note, however, that, while Clusters A, B and G are formed at high similarity levels, Cluster F is a single unit, or residual and Cluster D is combined at low similarity and is therefore a much weaker association of units.

There is as yet no measure for testing the significance of clusters formed by the average linkage method (Sneath, 1969; Sneath and Sokal, 1973). I therefore attempted to corroborate the results of cluster analysis using the ordering method of nonmetric multidimensional scaling (Shepard, 1962; Kruskal, 1964; cf. Sneath and Sokal, 1973).

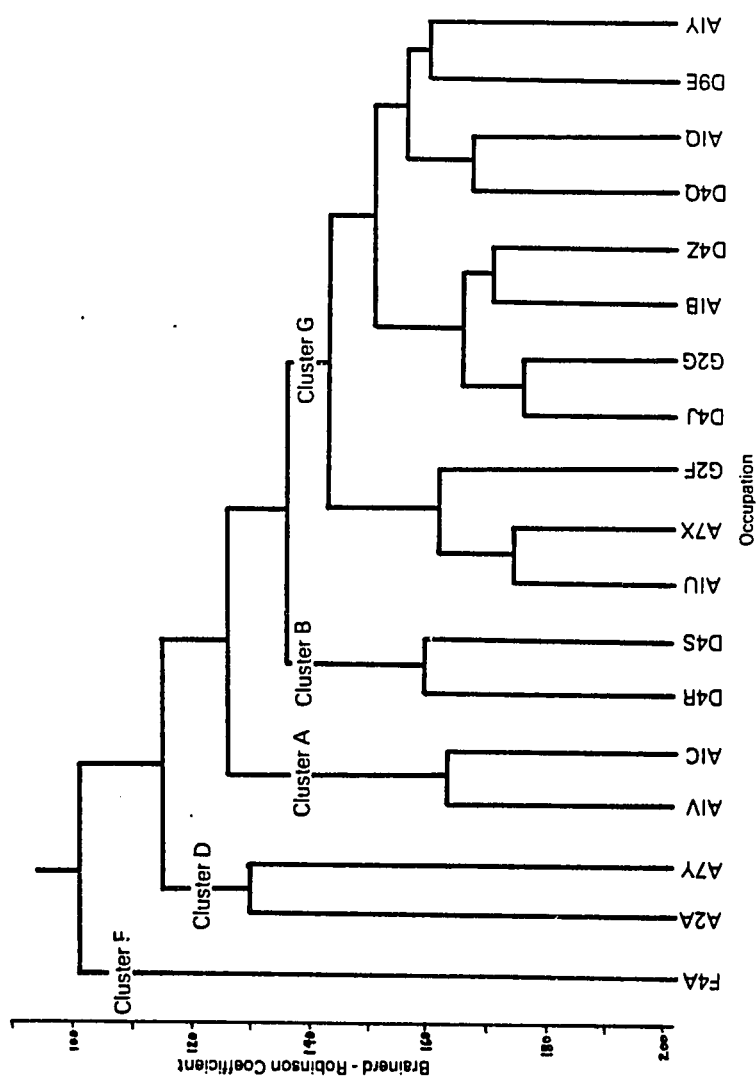


Figure 14. Average linkage clustering dendrogram for occupations in combined Groups 1 and 2.

I chose multidimensional scaling over the similar principle components analysis because the former method is better at giving balance to the relationship between both close and distant units. Principle components analysis tends to accurately portray dissimilarity distances between widely separated units, but obscures relationships between close units (Sneath and Sokal, 1973). Because many of the units in the present analysis, especially those in Clusters A, B and G have a high degree of similarity to one another and the similarities between these three clusters are fairly high, they will be close together in hyperspace. Principle components analysis might obscure the difference between these clusters, so multidimensional scaling is the more suitable method here.

Table 14. Matrix of Robinson Coefficients Comparing Occupations in Group 2 with Clusters Formed by Average Linkage Analysis of Group 1 Occupations*

Group 1 Cluster	Occupations								
	Cluster D		Group 2 Cluster E						Cluster F
	A7Y	A2A	A1U	G2F	D9E	D4J	G2G		F4A
A	130	116	132	105	108	112	122		109
B	129	90	130	122	126	144	134		114
C	128	104	150	145	147	153	154		111

*Figures are mean similarities.

Multidimensional scaling is increasingly in use by archaeologists both as a taxonomic and analytic tool (e.g., Doran and Hodson, 1975; Hodson et al., 1966; Johnson, 1972; Matson and True, 1974; cf. Cowgill, 1968) and has been employed to corroborate the results of cluster analysis, as Cowgill (1968) has advised (e.g., Thompson, 1978).

The method begins with a matrix of dissimilarity coefficients (or similarity coefficients for which the inverse is calculated) and arranges units in hyperspace such that the rank order of distances between each pair of units is inversely proportional to the dissimilarity between them. If the positions of all units in hyperspace are monotonically related to the ordinal relationships between values in the original matrix, a perfect ordering is attained. The degree to which a given ordering deviates from the perfect solution is measured as stress (Sneath and Sokal, 1973).

The number of dimensions for which stress is at a minimum is the number of dimensions needed to explain all variability in the data set. This number can be quite large, too large to be analytically manageable. The purpose of a multidimensional scaling analysis is to reduce this original number of dimensions to the smallest number that will account for the greatest amount of variance in the data set. This number is chosen by plotting stress values against the number of dimensions and observing where a sudden change, or elbow, occurs in the curve. The number of dimensions at which the elbow is observed is the number explaining the greatest amount of variance (Johnson, 1972).

Once the optimum number of dimensions has been identified, positions of all data points are displayed in a series of one or more plots, usually two dimensions at a time. Clustering can then be observed in positions of data points. One can also attempt to inductively interpret the meaning of each dimension by studying the dimensional plots with reference to various characteristics of units in the data set (e.g., Matson and True, 1974; Thompson, 1978; cf. Cowgill, 1968).

In the present analysis, I expected variability to be primarily in one dimension, that of function. Similarity values were calculated from percentages of types defined from functional attributes of wear and the types are identified as functional by virtue of their environmental distributions. Therefore, only "functional" variation as expressed by macroscopically observed patterns of edge

damage has been input. However, from Thompson's (1978) experience with multidimensional scaling, a second dimension seemed likely. Both of us are studying functional change through time. If change has occurred, one dimension in a multidimensional analysis is certain to be time. Thompson did in fact find time to be one of two principal dimensions explaining variability among Northern Puget Sound assemblages. A two dimensional solution is likely to be the best one for Pahsimeroi Valley occupations as well.

Occupations in Groups 1 and 2 were ordered using the TORSCA multidimensional scaling program developed by Torgerson and Young, available on the University of Washington's CDC 5000 computer. The similarity matrix was input in the same order as that used in the third clustering analysis (Figure 14) with units ordered roughly by sample size from smallest to largest. Analysis began with a maximum of four dimensions.

Stress values for dimensions 1 through 4 are graphed in Figure 15 showing distinct elbow and identifying two as the number of dimensions accounting for the majority of variance.

Figure 16 displays the plot of unit positions in two dimensions. Five spatially discrete groupings can be seen, corresponding to clusters A, B, D, F and G. Cluster C, the weakest cluster identified by average linkage, includes the units with the greatest spatial separation on this plot, and is the only cluster in which the units are not closer to each other than they are to any other unit in the analysis. Cluster D is best thought of as a pair of incidentally similar residual units.

In inspecting the diagram, with Thompson's (1979) findings in mind, I noted that the pattern of data points was indeed related to occupation (Chapter 6, Table 27). Generally speaking, occupations in the upper right are oldest, with the youngest occupations at lower left. Comparing rank orderings of occupations in Figure 16 with temporal order (Table 15), reveals a close correspondence with A. Spearman's rank correlation coefficient r_s of 0.887. With 17 pairs (occupation F4A is undated), significance to the .01 level is

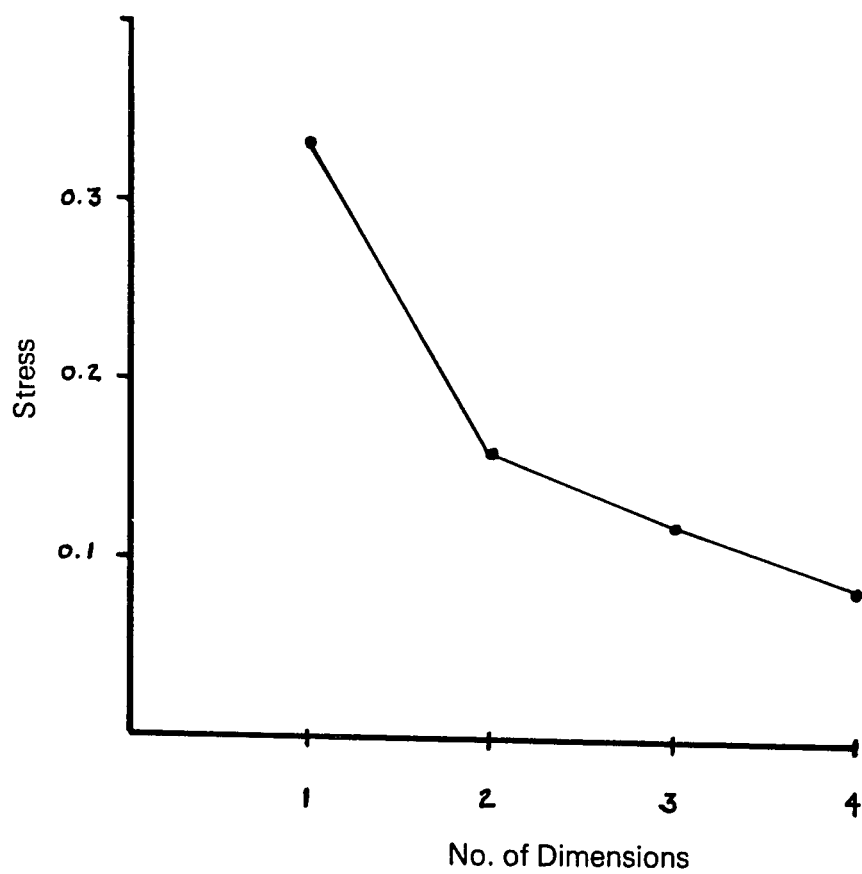


Figure 15. Graph of stress values for the nonmetric multi-dimensional scaling of Lithic occupations in Groups 1 and 2.

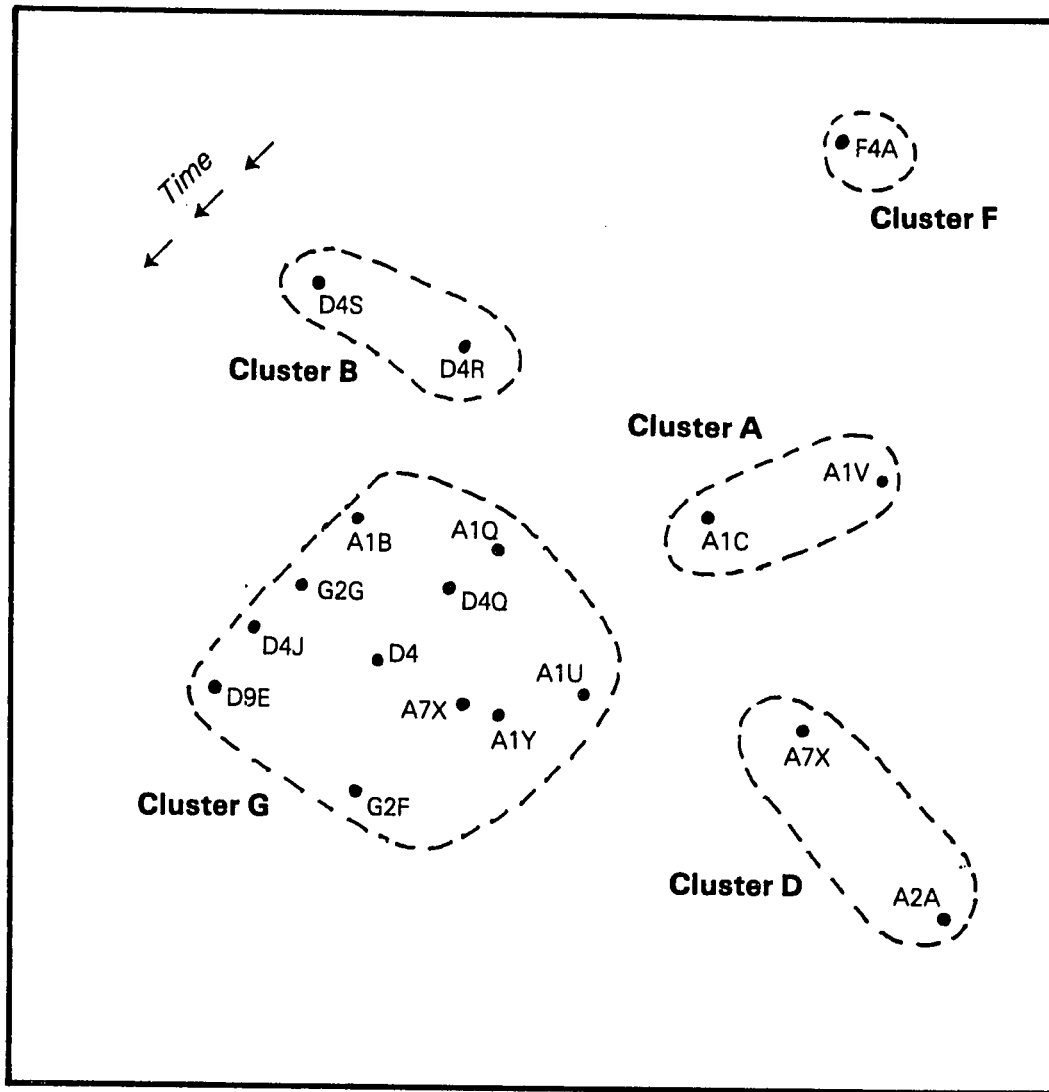


Figure 16. Plot of the two-dimensional solution to multi-dimensional scaling of Lithic Tradition occupations in Groups 1 and 2. One principal vector, time, is shown at upper left.

Table 15. Comparison of One Dimension in Figure 16 with the Chronology of occupations

Occupation	Order- upper right lower left	Temporal Order youngest-oldest
D9E	1	1
G2F	2	1
D4J	3	1
G2G	4	1
D4Z	5	7
A7X	6	5
A1Y	7	8
A1B	8	8
D4Q	9	6
A1U	10	15
A1Q	11	10
D4S	12	13
A2A	13	10
A7Y	14	10
D4R	15	14
A1C	16	15
A1V	17	15
F4A	18	--

between 0.564 and 0.601. There is thus a good chance that one of the two dimensions here is time.

There are at least two reasons why time may be a significant factor. One which I mentioned earlier is functional change, the other the extent of non-use related mechanical damage to tool edges which, for surface objects, is probably proportional to the age of an object.

The second dimension is probably related in some way to function, but for whatever reason the multidimensional scaling plot provides a grouping similar to that obtained from cluster analysis, corroborating the results.

Group 3 occupations. Thirty-one occupations (Table 16) contained sample sizes smaller than the total number of tool types (13) and multivariate statistical analyses could not be performed with any level of confidence. Similarities between units would simply have been too highly affected by sampling error. As an alternative, I grouped these occupations impressionistically, using tool type presence-absence and relative frequency as a basis.

At first, no intuitive groupings were discernible; each occupation seemed unique. Further collapsing of the number of variables was thus in order, and I cut the number from 13 types to 10 groups of types by combining concave and convex attributes in the shape of worn area dimension, thus combining types 1 and 7, 3 and 5, and 4 and 6. This decision is based on the observations of lithic use-wear specialists and my own experience with using stone tools. Whereas, the kind of wear, location of wear and faciality are all known to be related to the movements performed, to the force used to the materials being shaped (cf. Crabtree, 1972; Keeley and Newcomer, 1977; Odell and Odell-Vereecken, 1980; Semenov, 1964; Tringham, 1974). The shape of a worn area has not been studied extensively. However, my experience has been that, while concave wear is produced on an edge - and all the tools here are worn on their edges only - only when a small convex surface is being shaped.

Table 16. Basic Data on Occupations in Group 3*

Cluster	Occupation Stratum	Functional Types											Total 1-13	Type 0	N objects	Area in M ²
		1/7	2	3/5	4/6/11	8	9	10	12	13						
H	D4G XIV	4								1	5	12	17	200		
	G2B XIV	2									2	7	9	25		
	G2C XIV	3									3	14	17	120		
	A8V XIV	1									1	3	4	15		
I	A8X XIV	5		2			1				8	7	12	20		
	A8U XIV	3		1	1	1					5	1	5	50		
	A1X XIV	2	1	1		1		1		1	7	8	14	100		
	D1A XV	3		1	1	1				1	7	1	5	10		
	G1L IVb	3		2	2						7	2	6	60		
	D4F IVb	2		1						1	4	10	14	100		
	D9F XIII	1		1							2	4	6	10		
	G2D XIV	3		4		2				1	10	23	33	60		
J	D2B VI	1		1	4						6	10	16	70		
	C4A VI	1	1		2						4	2	4	25		
	A3C IVb	1	1		2						4	3	7	10		
	A3D IVb	1			3						4	8	12	65		
K	C5K XIV			1						2	3	7	10	200		
	A2B XIV			1						1	2	7	9	85		
	E3B I			1	2	1				1	5	5	8	45		
	C5H XIV			1	3					1	5	6	11	70		
	D1M XV			3	2					1	6	25	30	15		
L	D6A XIII				2						2	6	8	10		
	A8Y XIV				1						1	9	10	15		
	E3C I				1		1				2	2	4	10		
M	A4M XV										0		95	200		
	D2A VI										0		5	35		
	F2A I										0		5	60		
	A8Z XIV										0		17	35		
	G2A XIV										0		22	175		
R	D6B XIII									1	1	4	5	30		
G	D7X XIII	3		5	3					1	12	22	33	250		

*Occupations are arranged by cluster.

But this kind of use does not always produce concave wear. Therefore, convex-edged tools and concave-edged tools can conceivably have been produced by the same activity and reduction in the number of attributes in the shape of worn area dimension is again, least likely to affect our final perception of the patterns of activity distribution that comprise the settlement pattern.

This done, I placed occupations into groups impressionistically. The result: six additional clusters of occupations and two residuals that seemed to fit nowhere. One of these, D6B, comprises its own cluster R (for residual). The other, D7X is the largest occupation in Group 3 in both number of tools (12) and area (250 m^2) and compares well in terms of tool types with Cluster G, into which I have placed it.

Grouping by settlement area. Settlement area is accepted by many archaeologists as an index of the number of people occupying a site (cf. Cook, 1972; Cook and Heizer, 1965; Hassan, 1981; Naroll, 1972; Plog, 1975; Price, 1978; Zubrow, 1975). Whether or not such a correlation is warranted, settlement area certainly has something to do with the performance of activities at a site, whether it be the size of the participating group, dispersal of activities or duration of use. Therefore, I follow others (cf. Price, 1978; Willey, 1953) in treating this variable as a functional dimension in formulating settlement types.

Occupations in Cluster G, the largest ($N = 12$) and most variable group in terms of area (range - 150 - 1020 square meters; Tables 12, 13, 16) shows a strong tendency for bimodality (Figure 17). Six occupations are 750 square meters and another five are 400 square meters. The last member, at 600 square meters, lies between. Taking the sample mean ($\bar{X} = 590$) as the cutoff point, I have divided Cluster G into subclusters G1 (area $> 590 \text{ m}^2$) and G2 ($< 590 \text{ m}^2$).

Although some other clusters show wide variations in settlement area (e.g., B, H, I, M) none are populous enough for size distributions to be meaningful. Sampling error would be too important a factor. Therefore, Cluster G is the only group divided by area.

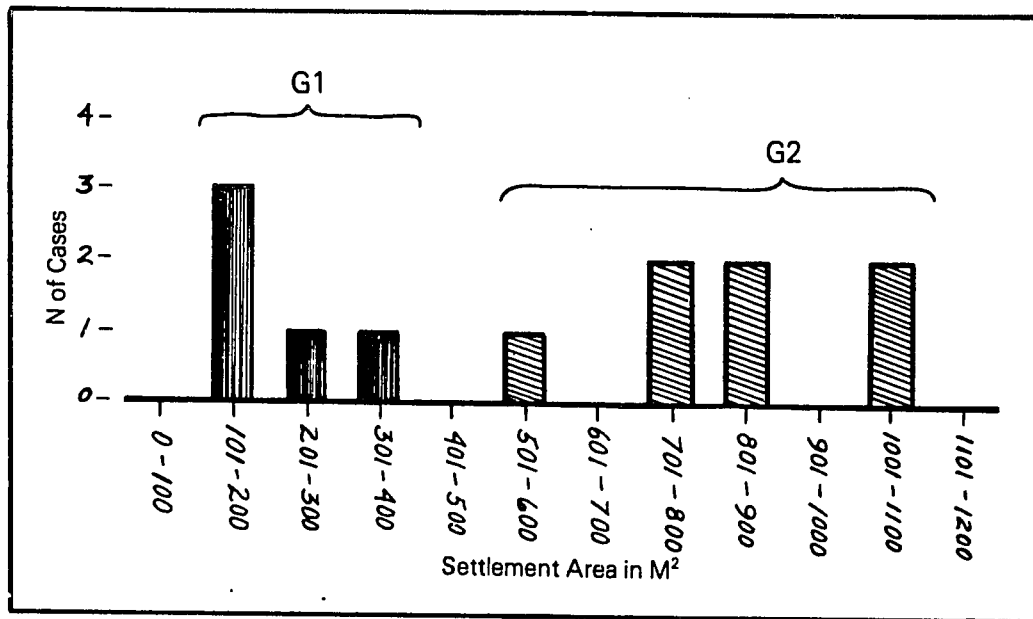


Figure 17. Size variation among settlements of Type G. Note the distinct bimodality between Groups G1 and G2.

Settlement types. There are now 13 occupation clusters, including A, B, D, G1, G2, H, I, J, K, L, M and the single member residuals F and R. These are the settlement types to be used in settlement pattern studies (Chapter 7) and are defined extensionally in Table 17. Type definitions are summaries of the characteristics which serve to distinguish members of each type and are, literally, average characteristics where larger occupations (Groups 1 and 2) are concerned. Tool types with mean percentages greater than 12 are included in the definitions (cf. Thompson, 1978). Definitions of types that include only Group 3 clusters consist of the average characteristics of type members.

Domestic and nondomestic settlements. The distinction between domestic and non-domestic is important if we are to be capable of observing the archaeological fitness of variant forms of the same settlement type. Although settlements are not assumed to have domestic functions (cooking, eating, sleeping), at least some of the 13 settlement types apparently are associated with such activity. I take house features, hearths, fire broken rock and burned bone as evidence of domesticity in surface occupations, characteristics shared by several occupations of Settlement Types A, G1 and G2. Occupations A1Q, A1U and A1V all contained stone circles. Excavations at A1Q (Chatters, 1976c; 1977) revealed bits of calcined bone and teeth. Calcined bone also occurred on the surface at Occupations G2G and D4Q, and a bone filled hearth was found in G2G (Chatters, 1977; see Chapter 8). Large stone circles, generally called house rings or tipi rings by North American archaeologists, often contain hearths (cf. Ranere et al., 1969) or are known from ethnohistoric records to have been the sites of skin or brush shelters (cf. Swanson et al., 1964). Hearths and burned bone are prima facie evidence of fire and are by definition domestic. Therefore, at least some members of Types G1 (A1Q, D4Q), G2 (G2G) and A (A1U, A1V) meet the criterion of domestic settlements.

Table 17. Settlement Types, Their Definitions and Membership¹

Type	Definition	Member Occupations
A	Occupations larger than 500 M ² which include: Type 1 (20%) Type 3 (18%) Type 4 (18%) Type 6 (18%) Type 13 (14%)	A1C A1V
B	Occupations larger than 400 M ² which include: Type 1 (47%) Type 4 (20%)	D4R D4S
D	Occupations larger than 100 M ² with Type 4 (24%) Type 13 (20%) Type 1 (10%) Type 3 (13%)	A2A A7Y
G1	Occupations larger than 590 M ² containing: Type 1 (32%) Type 3 (23%) Type 4 (15%)	A1B, A1Q, A1U, A1Y, A7X, D4Q, D4Z
C2	Occupations between 150 and 590 M ² containing: Type 1 (40%) Type 3 (28%)	D4J, D7X*, G2F, G2G, D9E
H	Occupations of varying size in which Type 1 is the only tool class present:	D4G, G2B, G2C, A8V
I	Occupations < 100 M ² in which types 1/7 and 3/5 are either the only types present or the most common (mean 45%) and second most common (mean 27%). Variable types are rare, with types 8 and 13 the most common.	A1X, A8U, A8X, D1A, D4F, D9F, G1L, G2D*
J	Occupations < 75 M ² in which Type 13 is absent and types 4/6 and 1/7 comprise nearly 90% of the assemblage.	
K	Occupations < 50 M ² in which Type 13 and Type 3/5 and/or 4/6 are the only tools present.	A2B, C5H, C5K, D1M, E3B*.

Table 17. (continued)

Type	Definition	Member Occupations
L	Occupations under 20 M ² in which only type 4/6/11 is present.	D6A, A8Y, E3C*
M	Occupations in which only unworn objects, Type O are present.	A4M, A8Z, D2A, F2A, G2A
F	Residual, 600 M ² in which Type 13 is absent and Types 4 and 1 dominate.	F4A
R	Residual of 30 M ² only containing one tool (Type 13)	D6B

¹Asterisks designate occupations placed into a type by best fit. These occupations may deviate somewhat from type definitions.

Referring back to Figures 14 and 16, it is evident that Settlement Types G1, G2 and A are more similar to each other than to Types D and F. Since at least some members of A and G1 and G2 are domestic, and all are similar to each other in the quantitative representation of tool types, these types of settlements are domestic. Likewise, because occupation Clusters G and A are about equally similar to Type B, this latter type will be called domestic as well, even though they contain no direct evidence of housing or fire.

The remaining large settlement types D and F will hereafter be called large non-domestic settlements; H, I, J, K, L, M and R are small non-domestic settlements.

Metallic Tradition

Artifacts attributable to the Metallic Tradition varied widely in form and material, including objects of steel, brass, aluminum, glass, ceramic, plastic, leather, rubber, cloth, wood and even stone. Special problems were encountered in the attempt to devise a functional classification for this assemblage. Most prominent among these were the absence of attributes such as wear patterns,

which could be logically related to the objects' use, and the need to overcome the biases arising from my participation in the culture that produced these objects.

This latter problem was surprisingly difficult to solve. As a participant of Euro-American culture, I knew intuitively what most of these objects had been used for. There were such things as beer cans, whiskey bottles, nails, shoes, horse trappings, fishhooks, rifle shells and hair curlers. These names reflect the ethnographic uses of the objects, a kind of folk taxonomy, and the categories might be employed as classes for functional analysis. However, ethnographic use and archaeological function are not equivalent qualities. Archaeological function is the relationship between artifact and environment (Dunnell, 1971a, 1978b), and the classes of objects which are environmentally patterned may not correspond to the classes which Euro-Americans use in their everyday life. Both this dilemma and the problem of identifying functionally meaningful attributes were resolved simultaneously.

Because archaeological function refers to nonrandom environmental distribution, the Metallic Tradition assemblage was carefully studied to identify those fields of artifacts (Dunnell, 1971b) whose members appeared to be environmentally patterned. Within those fields, attributes with disjunct distributions were also discerned. Provisionally functional classifications were developed for each of these fields through the intersection of dimensions of environmentally patterned attributes. These classifications were then tested by observing their distributions over microenvironmental strata to ascertain whether they were actually functional. In this analysis, it was not entirely possible to divorce myself from my Euro-American background and many of the attributes I observed were ones which I knew to be related to use of a given object.

Both discrete object and settlement classifications were formulated in this manner.

Discrete Objects

Functional classification. Fields at the discrete object scale which met the requirements for functional classification were containers, cartridges, fishing implements, shoes and horseshoes. Of these, classes of shoes and horseshoes were covariant with classes in the first three fields and were dropped as redundant.

Containers are hollow objects of varying composition and form for which there is some means of sealing contents inside. Cans and bottles belong to this field. Cartridges are more or less cylindrical brass objects with one open end and a closed end containing an explosive cap inside and a circular or linear indentation outside. The fishing implements field is a complex group of objects associated through context. A set of three hooks and four lead spheres were found attached to nylon line on one occasion. A drawing of the hooks, identifying them as fishing hooks was found in a small plastic box. Therefore, all these objects; plastic boxes, hooks, spheres, line and class of small steel box found labeled as a container of lead shot fishing line sinkers were grouped as fishing implements.

These three fields comprise 710 of 1382 Metallic Tradition artifacts. The remainder are predominantly nails and scraps of metal, glass, ceramic and other materials which exhibited no tendency for environmental patterning or which occurred too rarely to be of practical value to this analysis.

Attribute dimensions used for classification were chosen for their distributional characteristics or, in the case of containers, for their indication of probable contents. Containers with small openings were assumed to contain liquids; large openings were taken to indicate solid contents.

The dimensions I used in container classification are opening type, material, overall form and, in the case of cylindrical metal containers, diameter. With glass containers, volume in milliliters was also used. Both dimensions of continuous metric variables were formed into discrete units by observing discontinuities in size

distributions. Table 18 presents the attributes and their definitions. Classes formed in this hybrid paradigmatic/taxonomic classification which had denotata in project area collections are shown in Table 19.

The original nine container classes were collapsed to seven by combining IGBL with ISBL2 into Type M1 and ISBS1 with IGBS2 into Type M2. Labels found on denotata of these two pairs of classes indicated similar functions. Type M1 containers had been filled with solid food items such as peaches, cucumbers, carrots, potatoes and meat, whereas alcoholic liquids and sugar water solutions had been contained in objects of Type M2, regardless of the material from which they had been manufactured.

The cartridge field was classified by two dimensions, maximum diameter at the closed end and overall shape (Table 18). Again, the three resultant classes for which representatives were found are defined in Table 19. Fishing implements were so rare they are treated as a single class of object.

Thus we have 11 provisionally functional types, M1 through M11, including seven types of containers (M1 - M7), three cartridges (M8 - M10), and fishing implements (M11).

Environmental distributions of provisional types. Like lithics, the functional nature of Metallic Tradition types M1 - M11 was evaluated by observing their microenvironmental distributions (Table 20). Again, patterning is evident in each case. Figure 18 shows the proportions of six types present in more than three microenvironments of all types found in the seven strata with N of 15 or more. In no sense is any type evenly distributed. M1 is very common in Strata I, V and XIII, Type M2 in Strata IVb and XIV and so on. The functionality of the types is not reflected, and the types can now be used to create Settlement Types.

Features. The majority of features found during the project were assignable to the Metallic Tradition. Included among them were

Table 18. Functional Classification for Metallic Tradition Fields

Field I: Containers		
Dimension	Attribute	Definition
Material	S. Steel	self explanatory
	G. Glass	self explanatory
Form	A. Pocket	an elongate, flat box shape with opening in smallest surface.
	B. Cylinder	self explanatory
	C. Other	
Opening	L. Large	greater than 1/4 area of larger end of container.
	S. Small	less than 1/4 area of larger end.
Diameter (small opening metal cylinders only)	1.	60 - 80 mm
	2.	81 - 91 mm
	3.	over 91 mm
Volume	1.	under 200 ml
	2.	200 ml and over
Field II: Cartridges		
Shape	A. Tall cylinder	cylinder with height greater than 1.5 x diam
	B. Short cylinder	cylinder with height less than 1.5 x diameter
	C. Bottle	cartridge wide at closed end, constricting sharply toward open end (rifle form)
Maximum Diameter	1.	less than 10 mm
	2.	10 to 12 mm
	3.	greater than 12 mm
Field III: Fishing Implements		
All items considered as a unit because of the small number of objects in field (11).		

Table 19. Metallic Tradition Functional Types

Type	Classes	Number	Definition(s)
M1	ISBL	226	cylindrical steel containers with large open. cylindrical glass containers with large open., over 200 ml.
	IGBL2	14	
M2	ISBS1	98	cylindrical steel containers 60 to 81 mm in diameter with small openings. cylindrical glass containers over 200 ml with small openings.
	IGBS2	32	
M3	ISBS2	100	cylindrical steel containers 81 to 92 mm in diameter with small openings.
M4	ISBS3	21	cylindrical steel containers over 92 mm in diameter with small openings.
M5	ISAL	67	pocket shaped steel containers with large openings.
M6	ISCL	40	all other steel containers.
M7	IGAS1	3	pocket shaped glass containers with small openings, under 200 ml.
M8	IIA1	25	tall cylindrical cartridges under 10 mm in diameter.
M9	IIB3	25	short, cylindrical cartridges over 12 mm in diameter.
M10	IIC2	52	bottle shaped cartridges 10 to 12 mm diam.
M11	III	11	fishing implements.

Table 20. Environmental Distributions of Metallic Tradition Functional Types

Micro- environmental stratum	Functional Types											Total
	M1 N%	M2 N%	M3 N%	M4 N%	M5 N%	M6 N%	M7 N%	M8 N%	M9 N%	M10 N%	M11 N%	
I	195 (38)	83 (15)	97 (19)	16 (3)	48 (9)	35 (7)	3 (1)	18 (4)	8 (2)	8 (2)	9 (2)	520
II		1 (9)							9 (82)	1 (9)		11
III	1 (12)	4 (50)			1 (12)	2 (25)						8
IVa												
IVb	11 (22)	16 (33)	8 (17)	2 (4)	5 (11)				2 (4)	4 (8)		48
IVc	5 (16)	3 (10)			5 (16)	2 (6)			3 (10)	14 (45)		31
V	9 (42)		6 (28)		4 (19)			1 (5)		2 (10)		22
VI	1 (4)	4 (18)			1 (4)					17 (74)		23
VII	1											1
VIII		2 (67)				1 (33)						3
IX		5 (86)								1 (14)		6
X					1 (100)							1
XII		1 (100)										1
XIII	16 (46)	7 (20)	1 (3)	3 (9)	2 (6)			5 (14)	1 (3)			35
XIV	2 (9)	10 (45)						1 (5)	4 (18)	3 (14)	2 (9)	22
XV		1 (50)							1 (50)			2

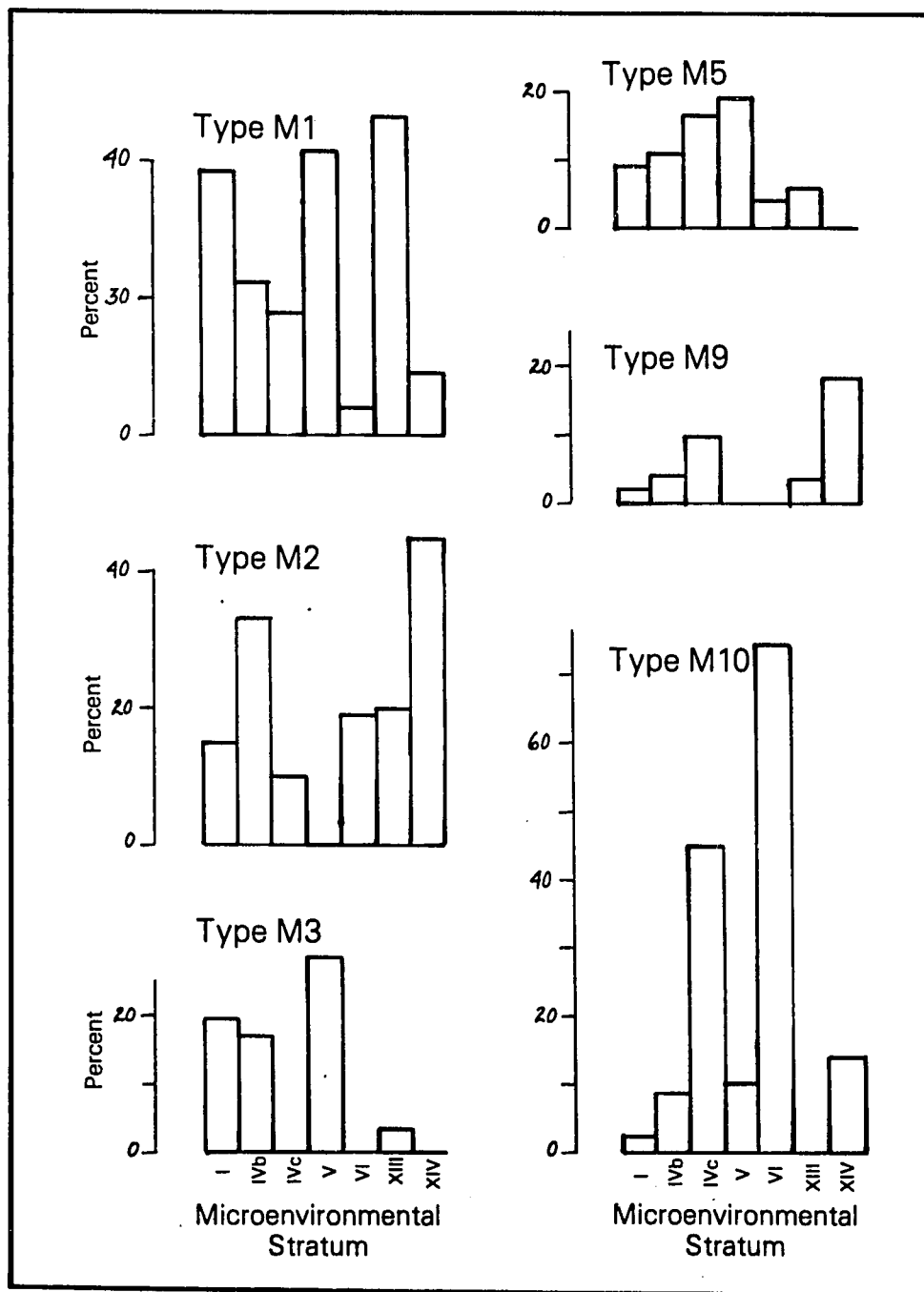


Figure 18. Microenvironmental distributions of the six Metallic Tradition functional types present in more than three strata. Percentages denote the proportion of each type among all items found in a stratum. Only the seven microenvironments with 15 or more items are shown.

small hearths, usually enclosed by circular rings of stone (14), small cairns or stone piles (6), a rubber tire filled with coarse salt, a 1 m diameter pit filled with containers and other refuse, portions of six irrigation ditches, one plowed field, an earthen dam and five wooden structures. Wooden structures were further divisible by their wall construction. Those with solid walls and roofs (whether intact or collapsed) will be referred to as buildings; open walled, roofless structures are corrals.

The functional nature of these crude categories is readily demonstrable, at least for the more numerous types. Hearths only occur in occupations without buildings or corrals, and visa-versa. Ditches began at streamside in the open plain, extending across the plain to plowed fields. Ridges and terrace escarpments are nearly always (5 of 6 cases) the site of cairns. Each type of feature consistently occurs in the same environments.

Occupation: Settlement types. Like their Lithic counterparts, Metallic Tradition occupations were grouped into settlement types by virtue of sample size and their content of functional types of discrete objects. Again, the first division is based on the number of things belonging to Types M1 to M11, and results in three groups: Group 4, $N > 350$; Group 5, $N < 100 \geq 1$, and Group 6, $N = 0$.

There is only one occupation in Group 4, F1Pe/F2Be, wherein $N = 375$. Not only is this occupation much larger than all others by a factor of 4, but it is the only occupation found in certain association with log buildings and a corral.

Group 6 also contains only one member, C40, which contained sawn wood, nails and a common table knife. This occupation could not be dated (Chapter 6) and will be discussed no further.

Most occupations (20) belong to Group 5 (Table 21), which I reduced to a set of smaller clusters using Average Linkage analysis. To do this, and in order to retain as many of the occupations as possible in the multivariate analysis, I again collapsed together the less populous classes of discrete objects. Here, that entailed only combining the rare container Type M4 ($N = 2$) with M6 (Other

Table 21. Distribution of Functional Types of Objects Among Metallic Tradition Occupations in Types MS1 and MS2

Settlement Type	Occupation	Functional Type										Total	Number of objects
		1	2	3	4	5	6	7	8	9	10	11	
MS1	C1A	6	1	2		2					1	12	39
	C1B	3	1	4		2					1	11	14
	E1H	8		6		3						17	17
	E3A*	1		1		1						3	7
	E3D*	1		1		0				1		3	4
	E3E	4				3	1					8	14
ungrouped	A3E					1						1	5
	A4N*	1	4			1					1	7	11
	A8V	1	8								1	10	18
	A8W	4	4								1	8	15
	B6P*		5									5	7
	C5J*		1								2	3	28
MS2	D4P*	2	2									4	11
	D6A	8	4		1		2		4			19	32
	D8X*	4	1	1								6	7
	E2Y*	1	1	1	1		1					5	28
	F1C	2	4	1					2			12	35
	F1P1	6	54	3		2			16		1	83	104
	F2B1	5	15			2						24	27
	F4B*	1							1			2	10

*placed by best fit.

metal containers), and combining together cartridges of Type M9 and M10. This left eight types for comparison (M7 is an empty set, being found only as isolated artifacts).

As before, only those occupations with N greater than or equal to the number of types were included in the cluster analysis; leaving only ten occupations (Because M9 occurred in none of these assemblages, its combination with M10 had no effect whatever). Brainerd-Robinson coefficients were the similarity indices used, with the result shown in Figure 19. There are two discrete clusters at the 100 level of similarity. Were I to follow the exact procedure used with Lithic occupations, multidimensional scaling would now be in order to support the grouping produced by average linkage. However, the two clusters are so distinct (one forms at the 135 level) that a similar result is certain.

Smaller occupations were grouped with the two clusters in Figure 19 according to best fit, resulting in two settlement types, Type MS1, with six members and Type MS2, with 13. One small occupation (A3E, N = 1) could not be placed. Occupation F1Pe/F2B1 from Group 4 comprises Settlement Type MS3.

Extensional definitions for Settlement Types MS1, MS2 and MS3 are presented in Table 22.

Summary

The purpose of this chapter has been to document the functional analysis and classification of discrete objects, features and occupations found in the Upper Pahsimeroi Valley. At the outset, I distinguished two traditions, Lithic and Metallic, which are commonly referred to as the prehistoric and historic archaeological records. Analysis of data from both traditions followed the model of function wherein classes are defined on the basis of characteristics related to their use and are tested through observation of their environmental distributions; the actual ethnographic use of objects is not a matter of central concern.

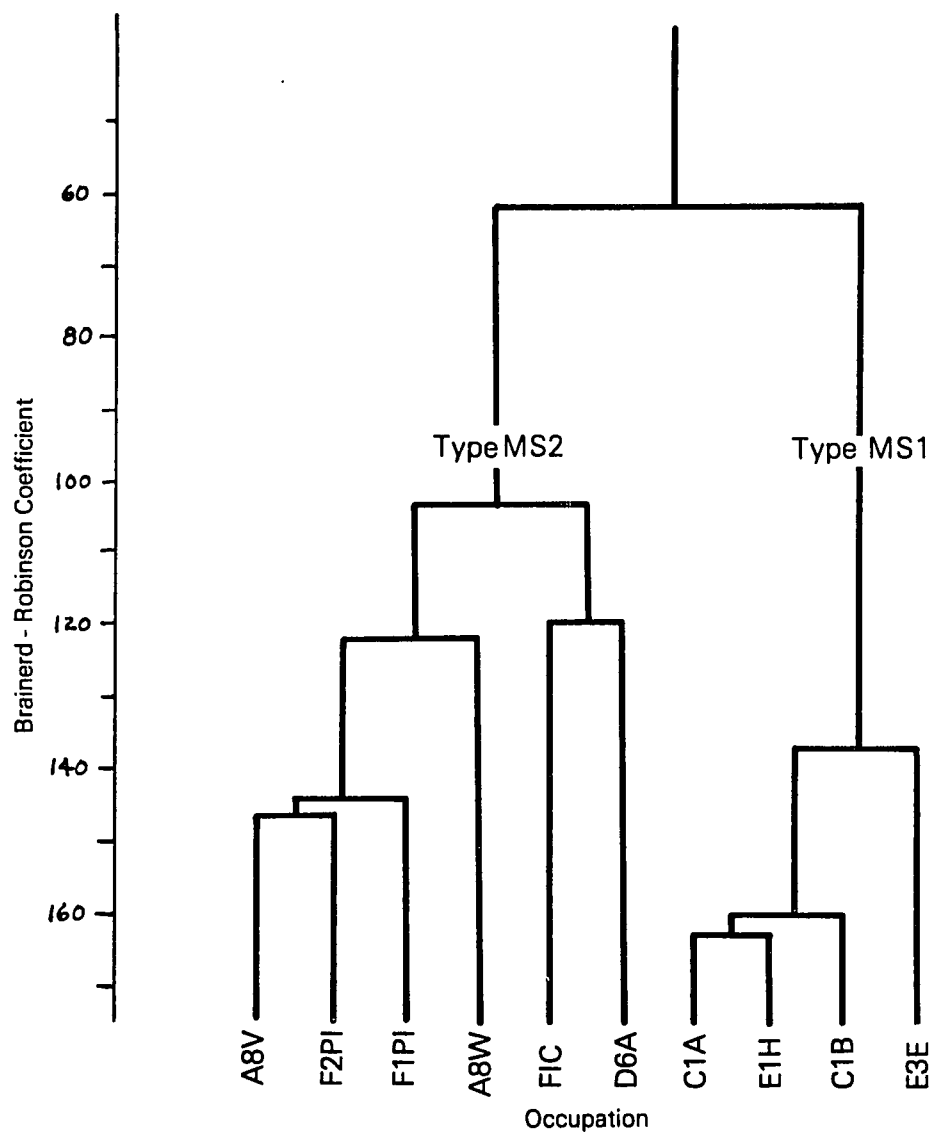


Figure 19. Average linkage clustering of Metallic Tradition occupations.

Lithic Tradition classifications were based on macroscopically observed attributes of use-wear and resulted in 14 functional types of tools. These tools then became the variables used along with sample size and occupation area to create settlement types by the multivariate methods of average linkage cluster analysis and multi-dimensional scaling and by impressionistic grouping.

Table 22. Extensional Definitions of Metallic Tradition Settlement Types

Settlement Type	Extensional Definition	Membership
MS1	Occupations with a predominance of types M1, M3 and M5, and less than 100 objects of all types. Buildings are absent.*	C1A, C1B, E1H E3A, E3D, E3E
MS2	Occupations in which types M1 and M2 are the most common containers and there are less than 100 objects in all types. Buildings are absent.	A4N, A8V, A8W B6P, C5J, D4P D6A, D8X, E2Y F1C, F1P1, F2B1
MS3	Occupations with over 300 objects in functional types 1 - 11 and associated with permanent buildings and corrals.	F1Pe/F2Be

*though adjacent to buildings, these occupations postdate abandonment of those structures as permanent habitations (Chapter 6).

Functional classes of containers, cartridges and fishing implements were created for the Metallic Tradition by the intersection of formal dimensions. Testing positively for environmental patterning, these classes, 11 types in all, were used, again with sample size, to devise three settlement types.

Features belonging to each tradition were also discussed briefly.

In both traditions I have used numerical taxonomic procedures to form settlement types from small samples of occupations.

Additionally, especially with Lithic Tradition occupations, I was often forced to rely on impressionistic means for forming types. The resultant type definitions are extensional (i.e., an enumeration of the qualities or group members [Dunnell, 1971] and the addition of new occupations to the assemblage with which I began will certainly change these definitions and possibly could alter the composition of occupation clusters produced by average linkage.) Because my samples are so small, the addition of even a few units to the analysis might have profound effects on type definition and membership, or it might not. In short, settlement types are weak because of small sample sizes, and this fact must be taken into account in evaluating the overall results of the Pahsimeroi Valley Study.

Patterning of these tool and object types and temporal variations therein are the subjects of Chapter 7.

CHAPTER SIX

Chronological Analysis

When research is concerned with the relationship between environmental and cultural events, accurate cross-dating is essential. One must be able to ascertain precisely the sequences of events. Because dating is so important, chronological analyses of Pahsimeroi Valley occupations and isolated artifacts included all the methods that were practicable. For Metallic Tradition manifestations, analyses included seriation (Dunnell, 1970; Ford 1949; Marquardt, 1978), stratigraphy, dendrochronology (Douglass, 1937; Stokes and Smiley, 1968) and the use of printed or stamped dates found on the artifacts themselves. Isolated artifacts could often be dated by index fossil approach, once a chronology of occupations had been developed.

Dating of Lithic Tradition materials was more difficult and less precise. Artifacts with stylistic variation were limited to a single class, projectile points (cf. Frison, 1978; Hester and Heizer, 1973) and these were in no case abundant enough for seriation. The materials required by other common dating methods such as dendrochronology, thermoluminescence and archaeomagnetism were absent. Carbon 14 was used to date one occupation (G2G), but the carbon was obtained through excavation and is more properly discussed in Chapter 8.

Obsidian occurred in most occupations, and obsidian hydration dating was thus a possible alternative. However, there are more than two dozen sources in Idaho and adjacent states from which obsidians could have been obtained, and hydration rates have not yet been calculated for any of them. Although this problem could be overcome with time, money and the cooperation of the regions' professional archaeologist, such an endeavor was outside the scope of the present study.

With the elimination of obsidian hydration as an alternative, only one dating method remained: the index fossil approach. This method and others applied to Metallic Tradition occupations are described below, along with the results of their application.

Note that all dates are presented in years BP in this and all subsequent chapters. This includes dates after 1950 (0 BP) which will be presented in + years BP. Hence, 1935 AD is 15 BP, 1965 AD is +15 BP. My purpose in using this convention is to stress the comparability of historic and prehistoric archaeological records.

Lithic Tradition Dating

The Northeastern Valleys Chronology

The projectile point chronology for the Northeastern Valleys of east-central Idaho was developed by Swanson (1972) using data from stratified rockshelter deposits in Birch Creek Valley (Swanson et al., 1964; Ranere, 1971) and the middle reaches of the Salmon River (Swanson and Sneed, 1966). My attempts to date Pahsimeroi Valley occupations by the index fossil approach using this chronology were beset by many of the problems which plague users of western projectile point chronologies in general.

Although Swanson formulated some of the types in his chronology and demonstrated their utility by the typological method (Kreiger, 1944), other types were either borrowed from the Great Basin chronology (Heizer and Baumhoff, 1961) or chronologies of the Great Plains (Mulloy, 1954), or were simply convenient groupings of artifacts, the historical relevance of which was not demonstrated (e.g., sharply-barbed and broad corner-notched types in Swanson, 1972). In addition, types were not intensionally defined and thus are often ambiguous (e.g., stemmed-indented base and Elko eared types). To further complicate matters, the temporal distributions of types that Swanson had not himself formulated were in several cases assumed to be equivalent to their distributions elsewhere,

even when dates from Swanson's own sites contradicted this assumption. A case in point is the Desert side-notched type.

This type was initially created by Baumhoff and Byrne (1959) for use in southeastern California, where it dated after 1100 AD (cf. Thomas, 1971a). Gruhn (1961) had found a similar form (Type 10) in Wilson Butte Cave, where it was a criterion of her Dietrich Phase, dated after 1300 AD. Although Swanson's own Carbon 14 dates would have ascribed a more recent date to the Desert side-notched type, he gave his Lemhi Phase, in which Desert side-notched types predominated, a span from 1250 AD to 1850 AD. Swanson evidently considered the earlier authors' findings to be unalterable precedents to which his own discoveries had to conform.

Because of these weaknesses in the existing projectile point sequence, I reanalyzed the Birch Creek projectile points in an effort to devise a chronology appropriate to the needs of the index fossil approach. The seven-step procedure I employed was similar to Kreiger's (1944) typological method, but with important differences.

Step One: Choice of the sites for chronology development. I chose to reanalyze the projectile points using only three stratified sites, 10CL3 (Veratic Rockshelter), 10CL10 (Bison Rockshelter) and 45LH45 (Bighorn Rockshelter). Two other stratified sites had been excavated and reported on by Swanson, but neither was suitable for my purposes. The Shoup Rockshelters (45LH23 and 45LH63 Swanson and Sneed, 1966) are not in the Northeastern Valleys but are, in fact on the historic ethnic boundary between the Northern Shoshone and the Nez Perces (Walker, 1971). Although we cannot presume the Shoup sites have always been on a cultural interface, the fact that they once were presents the possibility that different traditions of projectile point style may have intersected the sites differentially over the 8000 years of human occupancy. Jackknife Cave (Swanson and Sneed, 1971) is in the Northeastern Valleys, but extensive disturbance by both amateur archaeologists and nonhuman occupants of

the site, shallow deposits which were in many cases stratigraphically ambiguous, and a sequence of confusing radiocarbon dates make the data from this site suspect. The sites in Birch Creek are well dated, and stratigraphic descriptions of all three are thorough and well presented.

Step Two: Recording the attributes. Projectile point collections from all three sites were first given a cursory inspection to ascertain the dimensions along which they varied. After weight was discarded as useless because of the large number of fragmentary specimens in this and the Pahsimeroi collection, 17 variables remained for consideration. Shortly after beginning the detailed analysis of individual artifacts, I added two more. Attributes were thus recorded in 19 dimensions for each artifact (Table 23).

Not all projectile points were used in the analysis. Only those points which a study of flaking patterns revealed had not been resharpened or reshaped were used. Resharpened projectile points will often have different blade forms and flaking patterns from their unbroken contemporaries and reshaped projectile points may exhibit disparities among attributes due to changes in styles or flaking technology that may have occurred since their initial manufacture. Use of either could therefore potentially weaken the chronology.

In addition, only complete projectile points and projectile points with hafting device and a portion of the blade were used. Some attributes included in the analysis referred to characteristics of blade, notching or base; an object without all three could not be properly included even if it was identical in form with other artifacts called projectile points. I assume that if an artifact was worn it was not last used as a projectile point and may therefore have been collected from deposits predating its final resting place.

These limitations reduced the number of objects from several hundred to 188. Although this meant sample sizes for some periods

Table 23. Attribute Dimensions Used in Analysis of Birch Creek Valley and Wasden Site Projectile Points

Dimension	Definition
Blade form	Geometric shape of blade outline (blade is portion of projectile point between notches, if present, and tip or entire projectile point if notches are absent).
Blade length/width ratio	Maximum length, notches (if present) to tip divided by maximum blade width.
Blade cross-section	Shape of cross-section at widest point.
Cross-section T/W ratio	Blade width divided by maximum thickness at widest point.
Flaking pattern	Pattern formed by flake scars on blade, eg. parallel collateral, parallel oblique.
Side notching	Presence and form of notches in blade above corner; area between notch and base must be at least as wide as blade above notches.
Corner notching	Presence and form of notches at or below corner; area below notches must be narrower than blade above notch. Notch may be narrow, parallel sided to broad with margins forming a right angle or greater.
Stem form	Form of area below notching on corner notched projectile point; may be expanding, converging or parallel sided.
Stem/base L/W ratio	Length of stem (corner notched) or base (area below notches on side notched), measured from neck (see below) divided by width at widest point.
Shoulder form	The angle formed between a line drawn across upper margin of notches at neck and upper margin of notch outside neck. May be barbed, perpendicular or sloping (corner notched only).
Length of barbs	Where present, the relationship between barb length and stem length in corner notched points only.
Base plan	Overall plan of base from corner to corner, where present, or between points on blade 5 mm above base where corners are absent (as in elliptical blade).

Table 23. (continued)

Dimension	Definition
Basal notching	Presence of a single concavity at least .5 times as deep as it is wide, located in center of basal margin.
Neck width	Minimum distance between notches.
Edge grinding	Presence and location of abrasive dulling of flaked edges.
Surface grinding	Abrasion on surface near base, removing arises.
Material	Lithic material from which object was made.
Basal thinning	Presence of between 1 and 3 large flake scars originating at basal margin, extending along the blade axis beyond neck, if notched, or above 1 cm from basal margin, if unnotched.
Basal width/blade width	Width of projectile point 4 mm above basal margin divided by maximum width of blade.

of time would be quite small (see Step 7), there were nonetheless enough specimens for development of a working chronology.

Step Three: Identifying historical modes. Historical modes are cultural attributes with restricted temporal distributions. However, unless they are used as the only criteria for class definition (as in an index) attributes need not have a single, continuous distribution in time. The presence of side notches, for example occurs both in the early and late prehistory of both Idaho (Swanson, 1972) and the Northwestern Plains (Frison, 1978), with up to 3000 years between the two distributions. Side notches are, therefore historical modes, but are only useful in combination with other attribute dimensions.

To determine which of the 19 mode dimensions had historic utility, I inspected the temporal distribution of each attribute with the aid of an SPSS scattergram routine. For each dimension, the computer created a scattergram with the attributes of the dimension on the X axis and the strata of one of the three sites on the Y axis. Those dimensions which had the highest degree of temporal patterning were blade form, flaking pattern, side notching, presence of corner notches, form of corner notches, form of shoulder, neck width, stem/base length/width ratio, stem form and base plan (Table 24). These were the historical attributes used in subsequent classifications.

Step Four: Division of projectile points into fields. Once historic attributes had been recognized, two facts became readily apparent: (1) a classification in eleven dimensions would produce such a large number of classes that each object might well be unique, (2) some dimensions did not apply to all artifacts. While blade form, flaking pattern, side and corner notching and base plan are dimensions of all projectile points, others, most particularly those referring to shoulder, form of corner notching and stem form apply only to corner-notched specimens (i.e., side notched and

unnotched objects include the attribute "none" for all these dimensions). Neck width and stem or base length/width ratio do not apply to unnotched specimens, but included many of the attributes with the highest degrees of temporal patterning.

Both problems were circumvented by dividing the set of all projectile points into three fields on the basis of a single dimension: presence and form of notching. Corresponding with the working patterns of Kreiger (1944:279), these fields were corner-notched, side notched and unnotched. A small number of dimensions was then used in the classification of each field.

Step Five: Classifications. Once artifacts were divided into fields, they were identified as members of classes formed paradigmatically through the intersection of attributes from each of the dimensions in Table 24.

Step Six: Form classes into historic types. Not every class exhibits the distributional characteristics required of an historic type: temporal continuity and unimodality. Many classes also display covariant distributions and are redundant. It is therefore useful and necessary to combine classes into a smaller number of more inclusive units which do meet the requirements of the historic type.

To accomplish this recombination, the stratigraphic distribution of each class in each field was observed for each site. Those classes which were covariant were combined, as were classes which had discontinuous but complementary distributions (Table 25, for example). When this task was completed, 17 types remained, created by combination of the original 58 classes with denotata (Table 26).

Kreiger's steps three and four correspond to step six.

Step Seven: Intersite comparison. As a final test of the historic utility of the 17 types, I cross-dated the three sites used in the analysis plus two additional, single component sites,

Table 24. Dimensions and Attributes Used in the Classification of the Three Projectile Point Fields*

FIELD: Corner Notched			
Dimension	Attribute Number	Attribute Name	Definition
Corner notched form	1	Expanding	Notches diverging outward from neck more than 5° off parallel.
	3	Parallel	Notch margins do not diverge or converge from neck more than 5°.
Stem form	1	Expanding	Margins of stem diverge from neck at more than 5° off parallel.
	2	Parallel	Margins of stem do not diverge from neck nor converge from neck at more than 5° off parallel.
Shoulder form	1	Straight	Shoulder angle is no more than 5° toward stem or point.
	2	Sloping	Shoulder angle is greater than 5° toward point.
	3	Barbed	Shoulder angle is greater than 5° toward stem.
Base plan	1	Straight	Basal margin neither concave nor convex (see below).
	2	Concave	Overall plan of basal margin is concave to extent that concavity is more than 1/20 of base width.
	3	Convex	Overall plan of base margin is convex at more than 1/20 of base width.
Basal notch	1	Present	A concavity in basal margin width. Depth greater than 1/2 width.
	2	Absent	
Neck width	1	Narrow	Minimum distance across notches is 10 mm or less.
	2	Broad	Neck width greater than 10 mm.
Edge grinding	1	Base margin	Edge grinding on basal margin only or margin and sides of stem.
Edge grinding	2	Stem sides	Edge grinding on sides of stem only
	3	None	

Table 24. (continued)

FIELD: Unnotched			
Dimension	Attribute Number	Attribute Name	Definition
Blade form	1	Triangle	Blade is triangular with concave, straight or convex sides.
	2	Parallel	Sides of blade are parallel for at least 1/2 length before converging to point. Parallel within 10°.
	3	Broad base leaf	Sides of blade convex with greatest blade width more than 1.7 x width at 3 mm above base.
	4	Narrow base leaf	Convex sided blade with greatest width less than 1.7 x width at 3 mm above base.
Flaking pattern	1	Parallel	See Crabtree 1972:87, nos. 1 and 3; p.80.
	2	Parallel oblique	See Crabtree 1972:87, no. 2, p.59.
	4	Chevron	See Crabtree 1972:87, no. 7, p.59.
	5	Collateral	See Crabtree 1972:87, no. 4, p.52.
	6	Random	See Crabtree 1972:87, no. 4, p.86.
Base plan	as above	as above	as above
FIELD: Side Notched			
Blade form	as above, #'s 1, 2.	as above, #'s 1, 2.	as above, #'s 1, 2.
Flaking pattern	as above	as above	as above
Basal notch	as above	as above	as above
Neck width	as above	as above	as above
Base W/L ratio (base height)	1	Tall	Base W/L ratio less than 3.
	2	Short	Base W/L ratio greater than 3.

*Numbers used in class names follow the order of dimensions.

Table 25. Example of Step 6, the Formation of Classes into Historic Types*

Stratum	Classes												Stratum										
	C1			C2			C3			C4				C5			C6			C7			
10145	3	2	4	2	1	2							1	2	3						1	1	3
	4	1	3																				4
10CL10	3				1																		3
	5	1	1	1		1																	5
	7	1	1		1																		7
	11		1																				11
	13		1																				13
	14			1																			14
	15																						15
10CL13	19	1																					19
	20			2																			20
	21			3																			21
	22		1																				22
	23		1	1																			23
	24																						24
	25																						25
	27																						27
	F4																						F4
	29																						29
	F6																						F6
30																						30	
31																						31	

*The stratigraphic distribution of corner-notched projectile point classes is observed for each of the three sites (left margin) and those classes with coincident or complementary distributions are combined into Historic Types C1 through C7.

Table 26. Definitions of Historic Projectile Point Types in the Re-analyzed Northeastern Valleys Chronology*

FIELD: Corner Notched		
Type	Included Classes	Definitions
C1	2122124 2131214 2133214	Narrow-necked projectile points with expanding notches, expanding stems, barbed or square shouldered, any base plan with neither basal notching or edge grinding.
C2	3131214 3133214 3132214 3133114	Narrow-necked projectile points with parallel notches, expanding stems, barbed shoulders, any base plan, with or without basal notching but without edge grinding.
C3	2132214 2133114 2112224 2132224 2113124 2131124 2133122 2133124 3133124	Either: narrow-necked projectile points with expanding stems, expanding notches, a concave base, edge grinding, barbed shoulder and without a basal notch; <u>or</u> : narrow-necked points with expanding notches, a convex base, expanding stem, basal notch and barbed shoulders without edge grinding; <u>or</u> : broad-necked points with expanding notches, expanding stems, concave bases and barbed or straight shoulders without basal notch or edge grinding; <u>or</u> : all broad-necked projectile points with expanding stems, basal notches and either barbed or straight shoulders, all other criteria variable.
C4	2113221 2113222 2113224 2133221 2133222 2133224	Broad-necked projectile points with expanding stems, expanding notches, convex bases, barbed or square shoulders and no basal notching. The edge grinding dimension is variable.
C5	2312222 2312224 2212222	Broad-necked projectile points with parallel-sided stems, expanding notches, and concave, unnotched bases. Shoulders may be square or rounded, edge grinding is variable.
C6	3131221 3133221 3133224 3131224	Broad-necked projectile points with parallel notches, expanding stems, barbed shoulders and a straight or convex, unnotched base plan. Edge grinding is variable.
C7	2123224	Broad-necked, expanding notched and expanding stemmed projectile point with a convex, unnotched base, and rounded shoulders. No basal grinding. A tentative type because only a single representative was found.

Table 26. (continued)

FIELD: Side Notched		
Type	Included Classes	Definitions
S1	11221 11211 21221 21211 14221 26221 14211	Either: broad or narrow-necked projectile points with parallel-collateral flaking, triangular or straight-sided blades with a tall base and no basal notch; <u>or</u> : broad-necked points with random or chevron flaking, a tall, unnotched base and triangular or straight-sided blade; <u>or</u> : triangular bladed, narrow-necked points with chevron flaking, a tall base and no basal notch.
S2	16211 16221	Triangular-bladed, narrow-necked projectile points with random flaking, no basal notch and a tall base.
S3	16111 16121	Triangular-bladed, tall-based, basally-notched projectile points with random flaking and either a broad or narrow neck width.
S4	12212 16212 26212	Narrow-necked projectile points with short bases, random or parallel oblique flaking, a triangular or straight-sided blade and no basal notch.
FIELD: Unnotched		
U1	161 162 163	Triangular, randomly-flaked projectile points with any base plan.
U2	211	Projectile points with parallel-sided blades and parallel collateral flaking and a straight base.
U3	251 252	Projectile points with parallel-sided blades, expanding collateral flaking and straight or concave bases.
U4	421 422 423 453 463	Narrow-based leaf-shaped projectile points with expanding collateral, parallel oblique, or random flaking and straight or convex bases.
U5	322 362	Broad-based, leaf-shaped projectile points with parallel-oblique or random flaking and concave bases.
U6	361	Broad-based, leaf-shaped projectile points with random flaking and straight bases.

*For definitions of fields, see Table 20.

Table 27. Temporal Distributions of Historic Projectile Point Types in the Northeastern Valleys Chronology¹

Time Period (based on Table 20)	Stratigraphic Units CL3/CL10/other	Historic Types																	
		G1	G2	G3	G4	G5	G6	G7	S1	S2	S3	S4	U1	U2	U3	U4	U5	U6	Totals
100-400	19/1,2 /BT51	1							3	9		4							17
400-700	20/3/LE45, 3a	6	21			2			1	1	11	1							43
700-1300	21/4-7/ --	6	5		1	1	1	2				2							17
1300-1800	22,23/11/ LE45 4a	8	2		10		1												21
1800-2500	24/12-15/ --	2		1	7		1												11
2500-3000	25/ -- / --			4	2	5		1							1				13
3000-4000	26/16a,b/ --															1			1
4000-4500	27,28,F4/-/-			9	1	2		12							3	2			29
4500-6000	29/ -- / --					1		11											12
6000-7000	F6/18-30/ --							2*					1						3
7000-7500	30a/32a/ --			1		1		?						2	6				10
7500-8000	-/-/Nasden Bone Bed												1	5	4	1	2		13
8000-10500	30b,30c/32b/-							?						11					11
over 10500	31v/ -- / --							1						1					2

¹Time units are grouped on the basis of stratigraphic comparison and Carbon 14 date correlation - Figure 20.

*Type S1 is represented by numerous fragments in F6 at 10CL3, but only two specimens were sufficiently complete for the present analysis.

†Swanson ascribes artifacts on or near surface of 31 to 30c. I am attempting to present original data as exactly as possible and will not make the same assumption.

Desert Zone (10BT51) and Wasden (10BV30) and observed the temporal distribution of types from all sites across this master stratigraphic sequence. For cross-dating I used published radiocarbon dates, stratigraphic cross-dating already presented by Swanson (1972) and the distribution and relative abundance of projectile point types (seriation). Figure 20 presents the stratigraphic correlations and Table 27 displays the temporal distributions of types based on this stratigraphic chronology. Temporal units therein are the most precise divisions practicable, given available data.

The chronology presented in Table 27 is far from perfect, with one of its principal failings being the result of small sample sizes for the 3000 - 4000 and 6000 - 7000 year periods. This problem is largely due to the lack of data for the later time period and the necessity for eliminating fragmentary, resharpened, reshaped and worn specimens from both collections.

A second, more disturbing difficulty is evident in the temporal distributions of two unnotched types, U-5 and U-6. Both types persist for at least 5000 years, but both have markedly discontinuous distributions which bring their historic utility into question. Neither type is present between 7000 and 4500 BP. While their absence from 6000 to 7000 BP may be simply the result of sampling error, such an explanation is less tenable for the ensuing 2500 year period. The cause may instead result from change in the function of 10CL3, the only site from which a large sample of lanceolate projectile points were found in more than one geologic stratum.

It is possible that the unnotched projectile point was part of a distinct hunting technology from the one represented by large, notched projectile points. If that were the case, a change in the animals hunted in the vicinity of Veratic Rockshelter or in the season of year the site was occupied might have occasioned the use of the notched-point technology to the exclusion of the unnotched, thereby resulting in non-deposition of artifacts associated with the latter technology. Types U-5 and U-6 may be historic types within

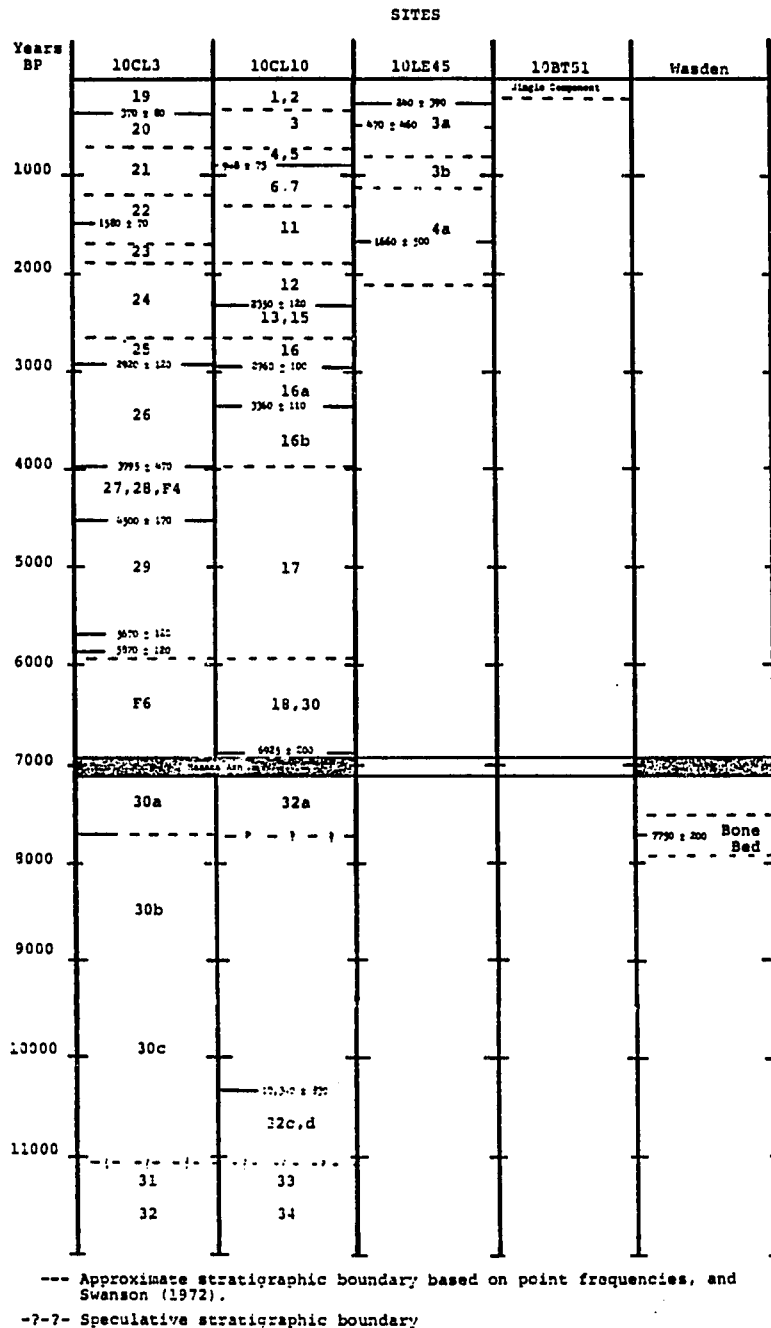


Figure 20. Stratigraphic correlations among sites used in formulation of the local projectile point chronology for the Northeastern Valleys, Idaho.

the field of unnotched projectile points, but do not appear to be such here because they are considered in comparison with types from the other fields. In fact, when the unnotched field is viewed in isolation, and a chronology devised for that field alone, the period from 4500 - 6000 BP poses no problem. There are simply no unnotched points available from that interval and it is operationally deleted. Except for the 6000 - 7000 BP span, when so few classifiable points are present in the field that deviations can be attributed to sample size, the resulting chronology of unnotched points meets requirements of the historical model: type distributions are continuous. I therefore include U-5 and U-6 among historical types, the temporary absence of which may be due to changes in the use of Veratic Rockshelter.

There are no other deviations from the ideal distribution of historic types that cannot be attributed to sampling error.

Dating Pahsimeroi Valley Occupations

Projectile points occurred in 29 of the Lithic Tradition occupations, 87 points in all, of which only 45 were complete enough to be identified with single types. Eighteen other projectile points were fragmentary, but could be identified as belonging to some member of a set of similar types with overlapping temporal distributions.

Dates were obtained by comparing the presence and proportional abundance of projectile points in each occupation against the presence and abundance of types in the Northeastern Valleys Chronology (Table 28). Where numbers were small, as in most occupations, dating was based on simple probability. A single projectile point in a site has a higher probability of belonging to a type common to the period of human occupancy than to an uncommon type. For example, a single projectile point of Type C-2 was present in Occupation D7X. A look at the master chronology (Table 27) reveals that Type C-2 is the predominant type between 400 and 700 BP, but that it is also codominant with Type C-1 from 700 to 1300 BP. D7X,

therefore probably dates between 400 and 1300 BP. A more complex example is Occupation D4S, containing three members of Type S-1, and one each of Types C-3 and C-5. The period during which S-1 is dominant and C-3 and C-5 are also present is 4000 to 7000 BP.

Note that the temporal sequence of occupations presented in Table 28 approximates the order of occupations found along the second variability dimension in the multidimensional scaling plot of Figure 16.

Occupations range in age from up to 8000 years BP to as little as 100 BP, with the largest numbers belonging to the periods 8000 to 6000 BP (3) and 2500 to 100 BP (21). The intervening 3500 years are represented by only three occupations. The significance of these figures will be discussed in Chapter 7.

Occupations without projectile points. Nearly half of all Lithic Tradition occupations contained no projectile points; all but one (F4A) belonged to Group 3. Because there were no projectile points and no other dating technique could be used with these surface occupations, I was forced to resort to less reliable means: dating by association with other members of the same occupation type, and by the presence of lithic materials coupled with the degree of surface weathering present on individual artifacts. Only some members of Occupation Types J and I could be dated by either means; the remainder were not datable. The ages of occupations in Types J, L, M and most members of H are thus unknown and these settlement types must be left out of subsequent discussions of settlement pattern.

Dating by Association

Projectile points occurred in four of eight members of Settlement Type I, and three of these occupations could be dated by the index fossil approach. All (D1A, D4F, A1X) were assigned dates between 700 and 2500 BP. Because the dated members of this settlement type are such a large proportion of the total and because

they are so close together in age, there is a strong probability that the other occupations of this type fall within the same age range. Therefore, all Type I occupations are assigned dates of 700 to 2500 BP.

Dating by Material and Weathering

The majority of lithic artifacts were made of the same or similar jaspers, chalcedonies, quartzites, cherts, ignimbrites and obsidians. However, one unique material occurred only in occupations of a single time period. The material was a smokey or silver-grey obsidian with small phenocrysts, and occurred only in occupations A1C and A1V, both of which dated between 6000 and 8000 BP. The only other finds of this lithic material were made in occupations A3C and A3D. It is likely, therefore, that these latter two occupations also date to 6000 - 8000 BP. This age assignment is supported by the degree of surface weathering seen on objects in A3C and A3D. Most artifacts recovered from occupations in the project area do not show extensive surface polish, regardless of their topographic locations. Four do: A1U, A1V, A3C, and A3D. All consisting of both obsidians and various forms of cryptocrystalline quartz. Because A1U and A1V are assigned to 6000 - 8000 BP, the assignment of the other two occupations to this same time period is appropriate.

Although it is tempting to date other J occupations by association with A3C and A3D, to do so would be unwarranted due to the indirect means by which the two A3 occupations were themselves dated.

Dating Isolated Finds

Projectile points were the only isolated finds that could be dated. For assigning ages to isolates, I first simplified the Northeastern Valleys Chronology into a bar graph (Figure 21) summarizing the time range of each historic projectile point type. The period during which a type was common (25% or more of all projectile

Table 28. Distribution of Projectile Point Types Among Lithic Tradition Occupations, Used to Determine Occupation Ages

Occupation	Projectile Point Type																	Total	Approximate Age Years BP	
	C1	C2	C3	C4	C5	C6	C ^{1/2} /6	S1	S2	S3	S ^{1/2} /3	S ^{1/2} /3	S4	U1	U2	U3	U4			U5
A1V															1				1	6000-8000
A1C								2									2	1	5	6000-8000
A1U								1										1	2	6000-8000
D4R								1											1	4500-7000
D4S			1		1			3											5	4000-7000
D4G																		1	1	3000-4500
A1Q			1	4															5	4000-7000
A7Y				3															3	1800-2500
A1Y			1				2												3	1300-2500
A2A			1				3												4	1300-2500
A1B							1												1	1300-2500
A2B							1												1	1300-2500
D1A							1												1	1300-2500
D4F							1												2	1300-1800
D4Z			1	1															10	700-1300
D4Q	3	1	3	1	1	1													1	700-1000
A1X																			1	400-1300
D7X																			3	400-700
A7X																			2	400-700
C5K																			1	400-700
C5H																			1	100-1800(300)
D6B																			2	100-400
G2F									2										2	100-400
G2G										1									1	100-400
D9E											1								1	100-400
E3B												1							1	100-400
D4J																			1	100-400
D1M																			1	100-400

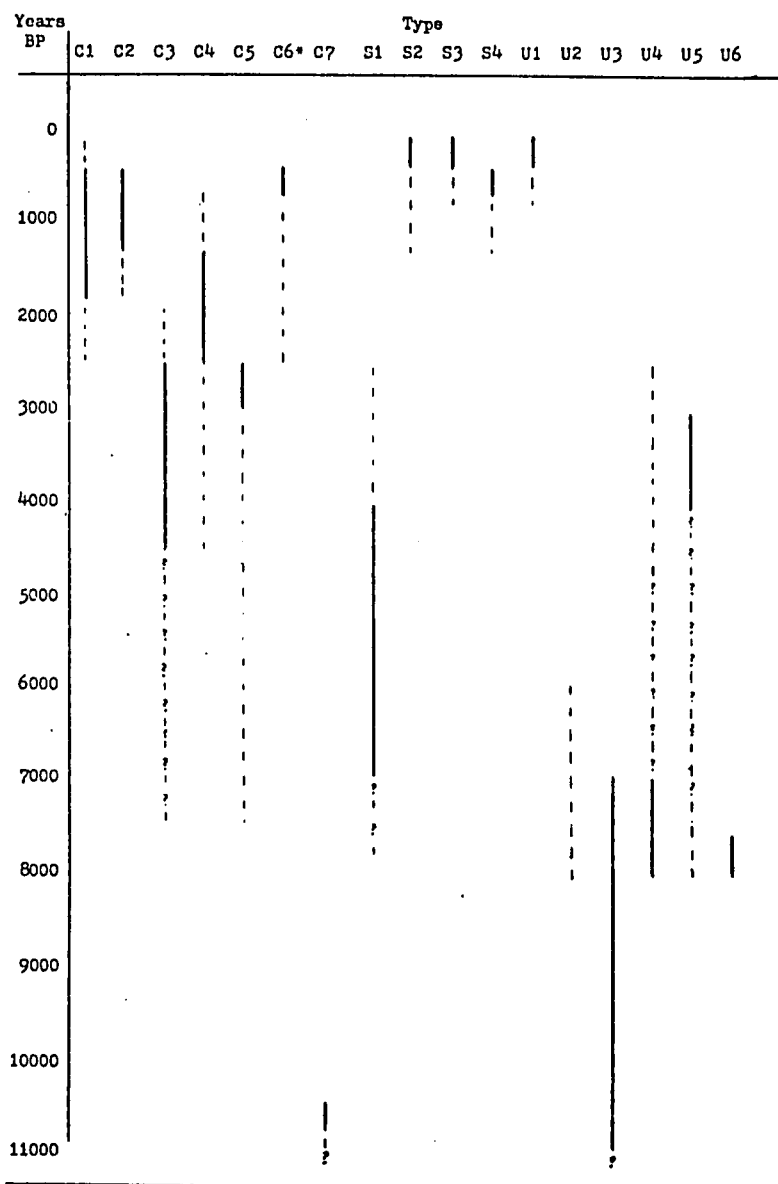


Figure 21. Ages of projectile point types in the Northeastern Valleys Chronology. A type's age range is the period during which its popularity is 25 percent or greater (solid line). Total ranges are shown by dashed lines.

*Type C6 is never common, but reaches highest proportions in the period 400-700 BP.

points during the period) is accentuated on the graph. This period is taken to represent the most probable age of an individual belonging to any specific type. An isolated member of Type C3, for example, would date between 2500 and 4500 BP; and S1 type has an age of 4000 - 7000 BP and S2, a date of 100 - 400 BP.

Any further discussion of the ages of isolated projectile points is more appropriate to the following chapter, where it is important to an understanding of changing patterns of land use.

Dating the Metallic Tradition

A variety of dating methods could be applied to Metallic Tradition manifestations, due to the better preservation of organic materials, the greater diversity of artifact forms and the presence of a written calendric system. Two relative and two absolute dating methods were used; seriations, stratigraphy, dendrochronology and written dates. Seriation was used to obtain a primary chronological ordering of occupations, after which stratigraphy demonstrated the temporal direction and the two absolute dating methods provided a time scale. All dates are presented in years BP to maintain consistency with Lithic Tradition ages. I recognize, however, that the dendrochronological or calendric dates presented here may vary from the Carbon 14 time-scale (Ralph and Michael, 1974).

Relative Dating: Ordering by Seriation

Seriation is a method which attempts to place occupations into temporal order by means of either the overall statistical similarity among occupations or the distributional characteristics of historic classes of artifacts. Various seriation techniques are now in use and these have recently been summarized by Marquardt (1978). The form of seriation I applied to Metallic Tradition occupations was the deterministic kind of occurrence seriation, which places occupations in order such that the occurrence of all historic types is continuous (Dunnell, 1970). This approach was preferable to the more precise frequency seriation in this case because numbers were

usually so small that sampling error would have had an inordinate degree of impact on the ordering of occupations.

To avoid the problem of spatial variation in the distribution of historic classes (Deetz and Dethlefsen, 1965; Dunnell, 1970; Ford, 1954; Phillips et al., 1951), I conducted two separate seriations of Metallic Tradition occupations and checked these seriations by observing the distribution of two historic attributes. Both seriations used historic classes of metal containers (cans), one classification distinguishing among the denotata of functional Class ISBL, the metal members of Type M1; and the other subdividing the membership of ISBS1, a class in Type M2. The historic attributes used as indices were plastic and pull tabs (Table 29).

The ISBL classification was created by intersection of two dimensions with known or expected historic meaning; seal type and wall form. The walls and ends of cylindrical metal containers were originally held together either by folding or solder (Hunt, 1959). Contents were poured into the container through a large hole in one end and the hole was closed with a sheet metal cap soldered in place. The container's contents were then heated and steam was allowed to escape through a pinhole in the cap. Finally, this hole was sealed by solder. After around 36 BP, containers were sealed by crimping the lid onto the cylinder wall after filling.

Although there was no such account available on wall forms, I had observed that all cans sealed by soldering were smooth walled, while walls of some crimp-sealed containers were ribbed. Ribbed walls still occur today, especially in tall, narrow cans used for fruits and vegetables. Because of this apparently patterned temporal distribution, I concluded that the dimension of wall form, whether a can was ribbed or unribbed, might be historical. Intersection of the wall form and sealing method dimensions produced six classes, three with denotata: U1, solder sealed container with smooth walls; U2, crimped containers with ribbed walls.

Classification of ISBS1 containers was based on the single dimension of material. Containers were either made entirely of

steel or included some aluminum in their construction. Choice of these attributes was based on the observation that aluminum is in use today on most containers of this type, but that some occupations with many ISBSI denotata contained no containers of this kind made with aluminum. Therefore, this dimension varied systematically over time.

Table 30 presents the seriation of 20 occupations, using all four classifications. Except for small occupations, placed in order of best fit, there is only one occupation that deviates from the seriation model: F1Pe/F2Be. A large occupation associated with permanent structures, F1Pe/F2Be is almost certainly of longer duration than all other units. Considering the fact that it contains ISBSI class S and ISBL classes U1 and U2 but lacks plastic, the duration of this occupation probably extends from the period during which E1H and E3D were in use (before 36 BP, Hunt, 1959) to the time of A8V. All other deviations from the occurrence model are best attributed to sampling error.

Stratigraphic Dating

Superposition (cf. Rowe, 1961) was used to provide a check on the temporal direction that might be ascribed to the seriation by virtue of known historical relationships between container seal types. F1C was superimposed on F1Pe on the floor of the largest log building assignable to F1Pe (Feature 1). The building is a cabin with a roof consisting of planks laid horizontally across the frame and covered with a thick layer of earth. Sometime since the abandonment of F1Pe, rodents chewed through several of the planks, and approximately two cubic meters of earth poured onto the cabin floor. Subsequently, a fire hearth bounded by a ring of stones was built on this earthen layer and the associated artifacts of occupation F1C were deposited. F1C therefore postdates F1Pe, confirming E1H and E3D as the oldest occupations; F1C and C5I as the youngest.

Table 29. Historic Classification Used in the Seriation of Metallic Tradition Occupations

FIELD: Cylindrical metal containers, functional class ISBL			
Dimension	Attribute		Definition
Seal type	1	Soldered	Container ends folded and soldered to cylindrical wall, one end with a ring of solder around a dot of solder in center.
	2	Crimped	Container ends crimped over cylindrical wall. No solder on either end.
Wall form	U	Unribbed	Cylindrical container walls smooth.
	R	Ribbed	Container walls embossed with two or more indented rings, around circumference of container.
FIELD: Cylindrical metal containers, class ISBS1			
Material	S	Steel	Containers made entirely of steel.
	A	Aluminum	Containers made from a combination of aluminum and steel or from aluminum alone.
FIELD: Plastic			
Inclusive of any object made from polymerized hydrocarbons.			
FIELD: Pull tabs			
Aluminum objects approximately 3 cm in length including a ring riveted to a teardrop or triangular-shaped piece of sheet metal.			

Table 30. Occurrence Seriation of Metallic Tradition Occupations, Conducted Simultaneously in Four Fields*

Occupation(s)	+ plastic	+ pull-tab	Historic Classes					
			FIELD-Funct. Class ISBL			FIELD-Funct. Class ISB51		
			r2	u1	u2	S	A	
C5J*	+	+	?		?			+
F1C	+	+	+		+			+
F1P1, F2B1 and D6A	+	+	+		+		+	+
B6P*	?	+	?		?		+	
C1A	+		+		+		+	
A8W*	+		+		?		+	
D8X*			+		+		+	
A4N	+				+		+	
F4B*	+				+		?	
A8V					+		+	
E3A, E2Y, C1B, D8X*, E3E, D6P					+			
F1Pe/F2Be				+	+		+	
E1H, E3D*				+				

*Asterisks denote small occupations inserted by best fit. Note that occupation F1Pe/F2Be does not seriate and appears to have a longer duration than other groups in the table.

Table 31. Absolute Dates on Metallic Tradition Occupations*

Occupation	BP Date	Method	Source of date	Event dated where applicable
F1P1	+21	Printed Date	Label on steel container	
F4B	+ 6	Stamped Date	Silver coin	
D4P	9	Dendrochronology	Fire wood, Douglas fir	Death of branch
F1Pe	9	Printed Date	Newspaper in laying box Fea. 8	Last cleaning of box
	30	Dendrochronology	Construction timbers, Fea. 8	Cutting of timbers (construction)
	26	Printed Date	Paper chinking, Fea. 1	
	38	Dendrochronology	Construction timbers, Fea. 1	Cutting of timbers (construction)
F2Be	+ 2	Dendrochronology	Sagebrush in corrals	Date of abandonment
	37	Dendrochronology	Construction timbers	Cutting of timbers (construction)
G1	16	Dendrochronology	Sagebrush in plowed field	End of irrigation or other intensive use
	30	Dendrochronology	Sagebrush in plowed field	Last plowing of field
G cabins	31	Dendrochronology	Construction timbers, new cabin	Cutting of timbers (construction)
	46, 52	Dendrochronology	Construction timbers, old cabin	Cutting of timbers, latter date = construction

*Dates are expressed in years BP (base date 1950 AD) and are derived from tree and sagebrush rings and printed or stamped dates on manufactured objects.

Absolute Dating: Dendrochronology

The temporal order produced by seriation was placed against a calendric time scale using dendrochronology and written dates. Dendrochronological analyses took two forms; dating by comparison of tree-ring chronology (e.g., Stokes and Smiley, 1968) and dating by determining the age of big sagebrush (Artemisia tridentata) now growing in areas formerly disturbed by human activity.

Dating of Douglas fir. A ring width chronology for Upper Pahsimeroi Valley Douglas fir was developed for use in dendrochronological analyses (Chapter 11). Douglas fir wood used in construction and for fence posts and firewood were dated by comparison with that chronology. Samples were collected by cutting short sections from logs or posts or by gathering whole branches from woodpiles adjacent to harths in sites far removed from living Douglas fir stands. At least two sections were cut from each building or corral, one from the top, the other from the bottom of structural walls. This was done to determine whether structures had been built all at once or had been either rebuilt or built over an extended period of time. Only a few sections were cut to avoid marring the aesthetic qualities of these historic buildings. Sample preparation and dating followed Stokes and Smiley (1968).

Two corrals, two fences, four log buildings and one occupation of type MS2 were dated (Table 31). Two of the log buildings were situated in Tract G, near transect G1 and were dated to provide a larger age sample of occupation Type MS3.

Sagebrush dating. Three features were dated by cutting sections from big sagebrush growing within them. The woody, perennial shrub Artemisia tridentata is among the plants that produce annual layers of xylem tissue (Diettert, 1938). In an extensive study of big sagebrush annual ring growth, Ferguson (1964) noted that, although microscopic growth rings may occasionally occur, he had never observed missing rings. Sagebrush occasionally produce false

growth rings, most often during the early years of a plant's life, but these rarely occur at high elevations or northern latitudes and are readily recognizable (Ferguson, 1964). Therefore, by counting the growth rings (actually arcs in the sagebrush), one can determine the age of individual big sagebrush with a high degree of accuracy.

The age structure of sagebrush in natural communities has been used to date range and forest fires which kill sagebrush plants (Quinnild and Crosby, 1958) and has been suggested as a means for dating anthropogenic soil disturbances such as plowing (Ferguson, 1964). Individual big sagebrush produce hundreds of thousands of tiny, burr-like seeds which are readily dispersed by wind action or adherence to mammal fur (Daubenmire, 1975). In the absence of competition, particularly from grasses, sagebrush will readily colonize disturbed areas, especially those released from intensive grazing pressure, forming dense stands of uniform age (Edward Bracken, personal communication).

This tendency for rapid colonization is the basis of sagebrush dating. Stem sections were cut at ground level from big sagebrush plants growing in two corrals and an abandoned field. These segments were numbered on-site and a rubber band placed around each to reduce the exfoliation of annual rings. Upon return to the laboratory stem segments were treated with glue to prevent separation of rings (e.g., Ferguson, 1964) and sanded smooth on one end using 60 and 120 grit garnet paper. Growth rings were counted with the aid of a 10X hand lens beginning with the white, partially grown outermost ring and including the pith. Counts were made on at least two lobes of each stem to insure accuracy. If the oldest plants in a stand belonged within a single, populous age class, the age of the oldest plants in that age class was equated with the date of feature abandonment.

Techniques for selecting the plants to be dated varied between features. In the restricted area of the two corrals in occupation F1Pe/F2Be, eight plants were cut from each corral, insuring that all sizes of plants were sampled. All individuals in both corrals were

the same age (+2 years BP [1952 AD] Figure 22). Sagebrush do not survive inside corrals when the structures are used to contain animals, so +2 years BP must date to within one or two years of the last use of both structures. When dendrochronological dates from corral walls are compared against sagebrush ages, it is evident these corrals and probably the associated buildings, were in use from 38 BP to +2 BP (1912/1913 to 1952).

A different procedure was used to select plants from the plowed field of Transect G1. First, a transect was laid out N-S across the field and the largest sagebrush on this line were cut (Five plants). Then sections were taken from all sagebrush growing within a 3 m radius of each large plant (13 plants). Ring counts showed two age classes (Figure 22). The four oldest plants had begun life between 30 and 32 BP, while the 13 other specimens' first year was between 15 and 17 BP (one plant could not be dated). There appeared to be two events associated with sagebrush colonization or survival in this site, but the age structure could also have been a natural phenomenon.

To investigate this latter possibility, a second set of big sagebrush was cut from along the same stream that flows through G1. Twelve plants were cut along a transect in G2, set the same distance from the stream bank as specimens from G1. Soils in both cases were moist, sandy loams. Sagebrush in the G2 area were uniformly larger than those from G1, and of the ten plants for which ages could be determined, eight were older than all G1 specimens. As Figure 22 demonstrates, there is no tendency for G2 specimens to form age classes. The age classes observed in G1 are almost certainly related to human activity.

Interpretation of the G1 age distribution relies on three observations: (1) sagebrush cannot survive under a plowing regimen, (2) the field in G1 had once been irrigated by ditches run from the small, adjacent stream, and (3) sagebrush can and often do survive in small numbers in pastures, provided grazing pressure is not too

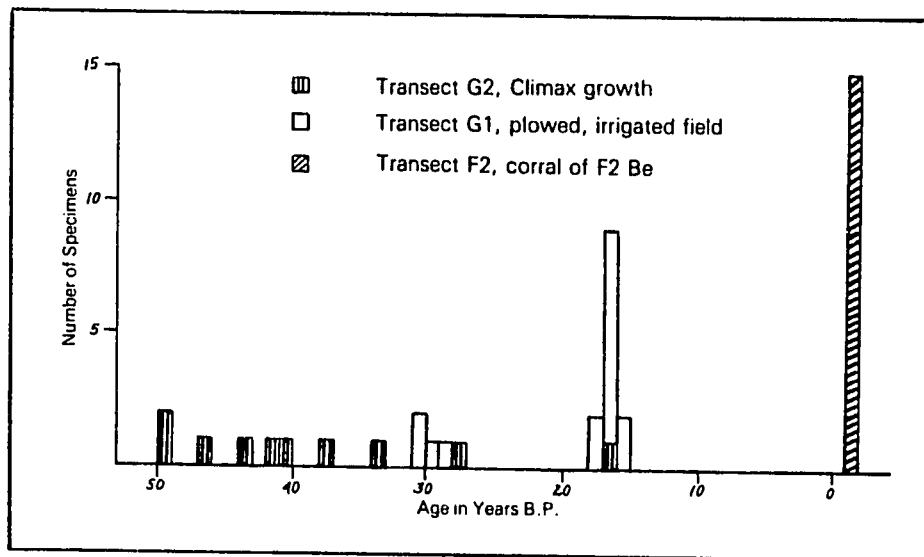


Figure 22. Ages of sagebrush plants from two Metallic Tradition features compared against the age distribution of a natural stand of the same species in a similar habitat.

intense, but they do not invade pastures in dense populations so long as grass cover is maintained.

These observations lead me to conclude that, although the field had been plowed after establishment of the associated MS4-type occupation (by 46 BP), plowing had ceased by 30 BP. A few sagebrush established themselves at or shortly after that time, but their numbers were kept low and new seedlings were prevented after original colonization, probably by grazing pressure from animals preferring other plants to mature sagebrush. Irrigation of the field maintained forage cover, preventing grazing pressure from forcing animals to feed on sagebrush leaves. In 17 or 18 BP irrigation and intensive grazing ceased, and sagebrush quickly colonized the exposed ground. The farmstead near transect G1 was therefore probably in use less than 30 years, from 46 BP to 17 BP.

Age Determination From Written Dates

The use of objects with dates carved, embossed or written on them has a long history in archaeology, particularly in the classical world and Mesoamerica, where dated coins and commemorative sculpture abound. Such written dates provide an oldest possible or terminus post quem date for the occupations with which they are associated.

Written dates were found on four artifacts from Metallic Tradition occupations, including two fragments of paper (both from F1Pe), a silver coin (F4B) and a cylindrical metal container with a painted label. Dates ranged from 1924 AD (26 BP) for paper used as chinking in F1Pe Feature 1 to 1971 AD (+21 BP) for the container from F1P1 (Table 32).

Chronology of Metallic Tradition Occupations

Dendrochronological and written dates can now be incorporated into the sequence of occupations ordered by graphic seriation both to confirm the chronological nature of the order and to add a time-scale to the sequence (Table 32). This completed, it can be seen that Metallic Tradition occupation began sometime before 46 BP and continued to the time of this study.

Dating Isolated Finds

Many of the isolated Metallic Tradition artifacts found in survey transects could be assigned dates based on the occurrence of similar objects in already-dated occupations. Comparing the seriation diagram (Table 30) against the chronology of occupations (Table 32), it is possible to establish limiting dates for the occurrence of pull tabs, ribbed cans (Type ISBL), and for aluminum cans (Table 33). The 38 BP date assigned to the change from solder sealed to crimp sealed cans of type ISBL came from Hunt (1959) and is supported by the chronology in Table 32. Two other common classes of isolated artifact must also be added; cartridges and

faunal remains. Ages for members of both fields were established by their occurrence in dated occupations and the results are summarized below.

Cartridges. Cartridges of all three functional types occurred in occupations, but only M9 (shotgun shells) and M10 (rifle shells) were common enough as isolated finds to warrant establishing a chronology. Rifle shells were present in enough occupations that data from Table 32 is sufficient to provide dates for historic types in this class. However, only one shotgun shell occurs in a dated context and other lines of reasoning have been necessary to devise a chronology for this type of cartridge.

Variation among rifle shells occurs in at least two forms; the series of letters and numbers found on the cartridge base (the manufacturer's identification and the caliber) and the presence or absence of a groove in the cartridge wall just above the base. Because the inscriptions on isolated cartridges often included names and numbers not seen in any occupation, this dimension could not be used. I have therefore had to rely on the grooving dimension. The temporal distribution of grooved versus ungrooved cartridges (Table 34) shows that the ungrooved type tends to be early, only found in an occupation that predates +2 BP, and that it is the more common type at that time. In dating isolated cartridges, I thus use +2 BP as a cutoff point between grooved and ungrooved rifle cartridges.

Shotgun shells are made with brass bases and plastic or paper walls. Plastic is already known to be a recent phenomenon (post +6 BP) but since paper-walled cartridges are still used occasionally, the distinction between paper and plastic doesn't provide for a facile age placement of particular specimens. Paper is perishable, however, and I have used relative preservation as a dating criterion. Since most shotgun shells occur in similar environmental settings (Strata XIV, IVb, IVc), environmentally-correlated, differential preservation should be a minor factor. The distinction is between cartridges from which the walls have

Table 32. The Chronology of Metallic Tradition Occupations*

Occupation	Age	Source of date
C5J	post- +21 BP	assigned
F1C	post- +21 BP	assigned
F1P1	post- +21 BP	written date
F2B1	post- +20 BP	assigned
D6A	post- +20 BP	assigned
B6P	cf. +10 to +20 BP	assigned
C1A	cf. +10 to +15 BP	assigned
A8N	cf. +10 to +15 BP	assigned
A4W	cf. +6 to +10 BP	assigned
D8X	+6 to +15 BP	assigned
F4B	+6 to cf. +10 BP	written date
A8V	9 BP to +6 BP	assigned
D4P	9 BP to +6 BP	assigned
E3A, E2Y, C1B, E3E	cf. 38 BP to +6 BP	assigned
F1Pe/F2Be	38 BP to +2 BP	various - see Table 28
E1H, E3D	pre- 38 BP	assigned
G1 Farmstead associated with plowed field.	46 BP to 17 BP	dendrochronology

*Assigned dates are determined from an occupation's position in the seriation.

deteriorated entirely, leaving no paper whatsoever or a rolled paper plug embedded in the cartridge base, and cartridges with walls at least partially intact. As it turned out, paper was either absent or walls were nearly intact, indicating that the makeup of paper between the two types may be different. But rotted paper correlated exactly with deep corrosion of the brass base and thus relative paper preservation probably does represent the passage of time. The single shotgun shell cartridge found in occupation E5A provided a minimum age for cartridges with rotted walls: +6 BP. Based on this date, I assigned shotgun shells walls of plastic or unrotted paper to the period after +6 BP; those with rotted paper are older, probably much older in most cases.

Table 33. Ages Assigned to Various Classes of Objects or Materials Belonging to the Metallic Tradition

Material/ Functional Type	Historic Type	Assigned Age Range
Plastic	_____	after +6 BP
Pull tabs	_____	after +6 BP
Can ISBL	r2 (ribbed)	after +6 BP
ISBL	u1 (soldered)	before 38 BP
M9	plastic wall	after +6 BP
	unrotted paper wall	after +6 BP
	rotted paper wall	before +6 BP
M10	grooved	after +2 BP
	ungrooved	before +2 BP

Faunal remains. Differential weathering was also the basis for dating skeletons or parts of skeletons (faunal units) found on the surface of survey transects. I assume that the extent of surface weathering on a bone is a function of the amount of time elapsed since the animal's death, all other things being equal. Since I

began the present study, Behrensmeyer (1978) has demonstrated the validity of this assumption through a taphonomic study of bone weathering in Amboseli National Park, Kenya. Bone weathers as its collagen component is chemically broken down. In Kenya the process requires less than two decades for even the largest skeletons to be reduced to unidentifiable shards. But in the dry, cool climate of the Pahasimeroi Valley, all chemical reactions would be slower than in tropical Kenya, collagen should last longer and skeletal remains are likely to have a longer surface life. The most deeply weathered faunal units found in the area might therefore be several decades old, a suggestion supported by the common discovery of deeply weathered skulls from bighorn sheep (*Ovis canadensis*). The species was locally extinct from around 1930 until the reintroduction of a small group in 1969 (Bill Hickey, personal communication) and the new population has yet to expand out of high elevation habitat.

Table 34. The Temporal Distribution of Grooved Versus Ungrooved Rifle Cartridges (Type M10) as Indicated by Their Presence in Dated Occupations

Occupation	Age	Grooved	Ungrooved
C5J	+20 to +25	2	
F1P1	+20 to +25	1	
B6P	+10 to +20	1	
C1A	+10 to +15	1	
A4N	+6 to +10	1	
A8V	9 to +6	1	
C1B	38 to +6	1	
F1Pe/F2Be	38 to +2	1	3

Bones were identified to three weathering classes, which correspond to the six stages recognized by Behrensmeyer (1978): (Class 1) fresh bone with at most a few cracks but otherwise intact (Behrensmeyer's stages 0 and 1), (Class 2) exfoliation of the outer bone layers, including bones with a coarse, fibrous surface from which small splinters can be easily removed (Stages 2 through 5), (Class 3) bone with lost integrity, having shattered into small, usually rectangular fragments (Behrensmeyer's Stage 5). Class 3 specimens were difficult to identify, but could be placed taxonomically using teeth, isolated landmarks and small, compact bones from the feet.

There are enough bones in dated occupations for weathering classes to be assigned approximate ages (Table 35). Bones belonging to Class 1 are the most recent, dating between +20 and +25; Class 2 is codominant with Class 3 in F1Pe/F2B1, dating 38 to +2 BP and Class 3 also occurs in earlier occupation E1H. Because of the overlap between Class 2 and Class 3 in the long-occupied F1Pe/F2B1, I arbitrarily assign a cutoff date between Class 2 and 3 midway during the use of that site, or around 20 BP. Thus Class 1 dates after +20, Class 2 from +20 to 20 and Class 3 before 20 BP.

Table 35. Dating of Faunal Remains Found on Transect Surfaces, Using the Distribution of Bones of Each Weathering Class Among Dated Occupations of the Metallic Tradition

Occupation	Age, BP	Weathering Class		
		1	2	3
F1C	+21 - +25	9	0	
C5J	+21 - +25	2	2	
F1P1	+21 - +25	4	0	
D6A	+20 - +25		1	
F1Pe/F2B1	38 - +2		4	5
E1H	38 - +2			1
E3A	older than 38			1

Summary

Chronological analysis is now complete. A new projectile point chronology for the Northeastern Valleys region of Idaho was first developed with data from stratified sites in Birch Creek Valley and then used to date Pahsimeroi Valley occupations by the index fossil approach. The new chronology will also be used in the next chapter to determine ages of isolated projectile points.

Seriation in four artifact fields provided an initial ordering of occupations from the Metallic Tradition; stratigraphy gave the order a direction and actual ages were then assigned from tree-rings and printed dates. Finally, chronologies for additional classes of artifacts and for faunal remains were devised, with ages obtained from the occupations.

CHAPTER SEVEN

Changing Patterns of Adaptation in the Upper Pahsimeroi Valley

The preceding two chapters entailed the functional and historical analyses of artifacts and settlements. At this point, functional archaeological units have been defined and have been placed in chronological order. I now present the sequence of settlement and land use patterns by combining the dimensions of time and function and by demonstrating the patterning of tool and settlement types over the natural environment for ten time periods. Differences among these time periods, when viewed in sequence can often be identified as change in patterns of human adaptation.

In the discussions that follow, I shall be looking at two aspects of adaptation. In identifying habitats as portions of the environment in which people were active, I am presenting the space dimension of the human ecological niche. Alternatively, patterns of artifact and settlement distribution within those habitats, as portions of the adaptive pattern of the human population, are empirical entailments of the behavioral phenotype itself. To the best of our ability to perceive from the archaeological record, these patterns are our fossil record of human adaptation, just as bones and teeth form the fossil record of Canids, Bovids or Teleosts. Thus, in this chapter I identify the subjects of study, behavioral variants of Homo sapiens, and the spatial portion of those organisms' niche.

Time Periods

Most often, archaeologists must perceive time as a sequence of units of varying size, units often centuries or millenia in length. We therefore must consider cultural history as a series of essentially static units, the duration of which is determined by our

ability to measure time. This ability, in turn, is dependent on rates of change in artifact form, the precision of chronometric methods and the number of absolute dates obtainable from the region under study. When rates of stylistic change are rapid, and/or when numerous, precise absolute dates have been obtained, archaeological chronologies consist of brief periods. Conversely, slow rates of change and few, precise dates permit only the definition of long periods, the beginnings and ends of which are often obscure.

A time period is treated here as a minimal archaeologically discernible segment of time for which sufficient data exists to enable the definition of patterns of settlement and land use. Boundaries between time periods are most commonly stylistic in the final analysis, stylistically distinct intervals having been originally identified by stratigraphic or chronometric relationships between occupations. Phases that comprise chronologies of North America and elsewhere are by and large stylistically bounded time periods (Taylor and Meighen, 1978).

In the present study, it has been possible to discern ten time periods (Table 36). For the Lithic Tradition, time periods are long, and in some cases overlapping, because projectile point style changes slowly, few archaeological investigations have been conducted in the area and the local chronology has not reached a high degree of precision. The duration of Metallic Tradition time periods is much shorter due to more rapid rates of change and precise dating of many occupations belonging to this tradition.

Difference and Change

In the following pages, I characterize settlement and land use patterns, portions of the adaptive pattern of human beings, for a sequence of time periods representing two traditions. For each period, the described pattern is a summary model which arbitrarily combines the products of human activity that have actually been deposited continuously and creates from them a static picture which we perceive as representing the adaptation of people living during

that period. When we place these pictures in temporal sequence, we may observe that any two adjacent periods X and Y are dissimilar in one or a number of respects. This observed dissimilarity is a qualitative distinction, a judgement that X is unlike Y, and does not necessarily connote the occurrence of adaptive change.

Table 36. Time Periods Used in the Study of Change in Land Use and Settlement Patterns in the Project Area

Temporal Unit	Dates in years BP	Duration	Tradition
Period 10	+20 to +25	6	Metallic
Period 9	+ 6 to +20	14	Metallic
Period 8	38 to + 6	44	Metallic
Period 7	38 to 80-100	42-62	Metallic
Period 6	100 to 400	300	Lithic
Period 5	400 to 1800	1400	Lithic
Period 4	1300 to 2500	1200	Lithic
Period 3	2500 to 4000	1500	Lithic
Period 2	4000 to 7000	3000	Lithic
Period 1	6000 to 8000	2000	Lithic

Change is an active concept; it is the process of being altered or becoming dissimilar. When we state that the adaptation of Period X changed into the Period Y adaptation, we are saying that X has become Y; it is Y's ancestor. Dissimilarity per se is merely the empirical quality of difference and does not imply process or connote change.

To say that change has occurred, we must demonstrate that the adaptation of Period X, through a continuous sequence of events, becomes the adaptation of Period Y. The key to solving this problem is the concept of continuity. If, by some means, we can show that the culture of Period Y had its roots in the cultural system of Period X, that they were "genetically" related in the sense meant

by Rowe (1961) and Rouse (1967), then we correctly identify the difference between X and Y as change. The empirical referent of genetic relationships is stylistic continuity or at least continuity in the presence of historical types of the kind required by the Frequency and Occurrence Laws of seriation (Dunnell, 1970; Rouse, 1967; Rowe, 1961; cf. Madsen and Berry, 1975). If the occurrence of artifact styles or historic classes of artifacts overlaps between time periods, "genetic" continuity is said to exist. If no overlap occurs, there is no demonstrable relationship between sequential time periods; different traditions are represented.

In the archaeological record of the Project Area, there are two artifact traditions, Lithic and Metallic. As evident from the Northeastern Valleys' projectile point chronology (Figure 21) and the seriation of Metallic Tradition occupations (Figure 30), continuity in historic classes exists throughout each tradition. Differences in adaptive pattern between periods within each tradition are properly identified as change. However, since no continuity exists between the traditions, the dissimilarities between Period 6 (Lithic) and Period 7 (Metallic) represent separate adaptations. My intent here is to explain change within a cultural lineage, rather than the replacement of one lineage by an entirely new one. Although both phenomena are evolutionary and may be the results of natural selection, I make no effort to account for the replacement of the Lithic Tradition by the Metallic Tradition.

Time Periods and the Scale of Change

The perception of time as periods rather than as a continuum has a profound effect on the precision with which changes in adaptation can be studied. Change along the stylistic dimension, which most often forms the boundaries of time periods, does not necessarily proceed at the same rate as change in functional dimensions. Functional changes may therefore occur within time periods delimited on the basis of style. In fact, a change between two periods that we perceive as a single event may actually be the sum of many

smaller scale events; we cannot determine which. These possibilities affect our understanding in two ways.

First, our perception of the date at which a change occurs may be hampered by the impression of our temporal units. Since we view adaptations as summary models and change by a comparison of such models, we perceive change as occurring abruptly, at the boundary between periods, when in reality the events that resulted in the observed dissimilarity are more likely to have occurred an unspecified time before or after the period boundary. When our purpose is to determine the relationship between cultural and environmental changes, intending to identify the cause of cultural change, dating is of supreme importance. If an environmental change is to be identified as having altered the selective forces acting on human adaptations, thereby precipitating change from one cultural form to another, we must demonstrate that the environmental event preceded or at least coincided with the cultural one. The imprecision with which we are able to date changes in human adaptations thus compromises our ability to demonstrate such a relationship, in that a cultural change, recognized at a period boundary and environmental change may or may not coincide for reasons unrelated to their actual times of occurrence.

Second, the lengths of time periods affect the scale at which change is perceived. A question currently being hotly debated by evolutionary theorists is the tempo of evolutionary change (e.g., Gould, 1980; Gould and Eldredge, 1977). Does evolution proceed through the accretion of gradual changes of small scale, in response to selective pressures in the environment (e.g., Ayala, 1978; Gingerich, 1977; Harper, 1975; Mayr, 1963, 1978; Simpson, 1969) or does it occur in saltatory fashion, with short periods of change, often catastrophic change in morphology, punctuating long periods of homeostasis (Eldredge and Gould, 1972; Gould, 1980; Gould and Eldredge, 1977; Stanley, 1976; Valentine and Campbell, 1975; cf. Bush, 1975, 1981; Carson, 1975; King and Wilson, 1975; White, 1978; Wilson et al., 1974; Rightmire, 1981), or perhaps both (Jones, 1981)?

Archaeology may be able to answer these questions for the processes of evolution in human behavioral adaptations (Chatters and Hackenberger, n.d.) but our ability to do so in any particular case is closely dependent on the lengths of our time periods. Sudden, quantum changes in the form of human adaptation may appear to occur as the result of speciation-like events that happen as a sudden, catastrophic reorganization of peoples' modes of adaptation (e.g., Plog, 1977; Renfrew, 1978; Snow, 1981) but may actually be the product of gradual selection for increasingly adapted forms of behavior. By periodization of the record, usually a necessary procedure, we may create a punctuated record from a gradual one and may not be able to distinguish which evolutionary mode is involved unless our time periods are extremely short, approximately the length of one or a few human generations.

With relatively long time periods in the Lithic Tradition, my ability to perceive the tempo of change is limited, not so with the 100-year long Metallic Tradition.

Land Use Patterns

Procedure

Land use is differential utilization of the natural environment and the land use pattern is the differential distribution of functional classes of artifacts over the natural environment (Dancey, 1973). In this instance, only isolated artifacts, both discrete objects and features, are the subjects of study (Chapter 5). Land use patterns for time periods in each cultural tradition are defined through a three-step procedure which serves to identify those microenvironments which were intensively utilized during each tradition, referred to hereafter as habitats, to assess which of the habitats were utilized differentially, and to determine whether there has been change in the utilization of habitats through time. Each step is discussed in the following sections along with its results.

Habitats

Habitats for each tradition were identified by observing the density of isolated artifacts recovered from each of the 17 micro-environmental sampling strata (Table 37). Isolated remains of domestic fauna, although they are considered here to be artifacts, are not included in the values of Table 37. Independently mobile creatures, domestic stock might have ranged freely among the area's microenvironments. Due to the concentration of predators and other severe environmental hazards or to the animals' tendency to huddle in sheltered areas during winter storms, deaths may have occurred more often in some microenvironments than in others. The micro-environments in which remains were found may not, therefore, reflect the environments in which animals were most active and inclusion of domestic remains in Table 37 might obscure actual patterns of human utilization. Domestic fauna will be considered in the section on Changing Land Use, and in Chapter 8.

Table 37 shows that there are some microenvironments, such as III, IVa and X with very low densities in both traditions, while high artifact densities consistently occur in Microenvironments I, IVc, V, VIII and XV. I assume that little or no activity took place in the microenvironments with low artifact densities and that people concentrated their land use activities in high density micro-environments. To objectively distinguish between rarely used and heavily used microenvironments, I studied the distributions of artifact density values for each cultural tradition (Figure 23). Disjunct, bimodal distributions are evident in both cases, with a more distinct bimodality occurring in the Lithic Tradition. In each case, density values are below $0.2/10^3\text{m}^2$ or above $0.4/10^3\text{m}^2$ with no values between. I arbitrarily designate the midpoint between these values ($0.32/10^3\text{m}^2$) as the cutoff point between microenvironments called habitats and those which data indicate people rarely used.

Lithic Tradition habitats were I, IVb, IVc, V, VI, XIII, XIV and XV. The group of habitats for the Metallic Tradition is very similar, including I, IVc, V, VI, XIII, and XIV plus II. This

Table 37. Density of Isolated Artifacts, Expressed as Artifacts Per Thousand Square Meters, for the 17 Microenvironmental Strata

Stratum	Surveyed Area meters ²	Lithic Isolates		Metallic Isolates	
		Number	Density	Number	Density
I	22,100	43	1.94	13	.59
II	13,300	0	0	12	.90
III	220,710	3	0.01	13	.06
IVa	5,785	1	0.17	0	0
IVb	49,125	28	0.57	10	.20
IVc	47,000	20	0.43	24	.51
V	6,900	7	0.87	11	1.60
VI	25,850	18	0.69	18	0.69
VII*	20,350	0*	0*	1*	0.05
VIII	25,500	4	0.16	5	0.20
IX	9,000	1	0.11	1	0.11
X	41,300	0	0	1	0.02
XI	8,050	NA	NA	NA	NA
XII	41,650	1	0.02	2	0.04
XIII	17,900	12	0.67	26	1.45
XIV	65,150	44	0.68	28	0.43
XV	35,325	21	0.59	5	0.14
		$\bar{x} = .43$		$\bar{x} = .43$	

*Microenvironment not sampled at same proportion as others.

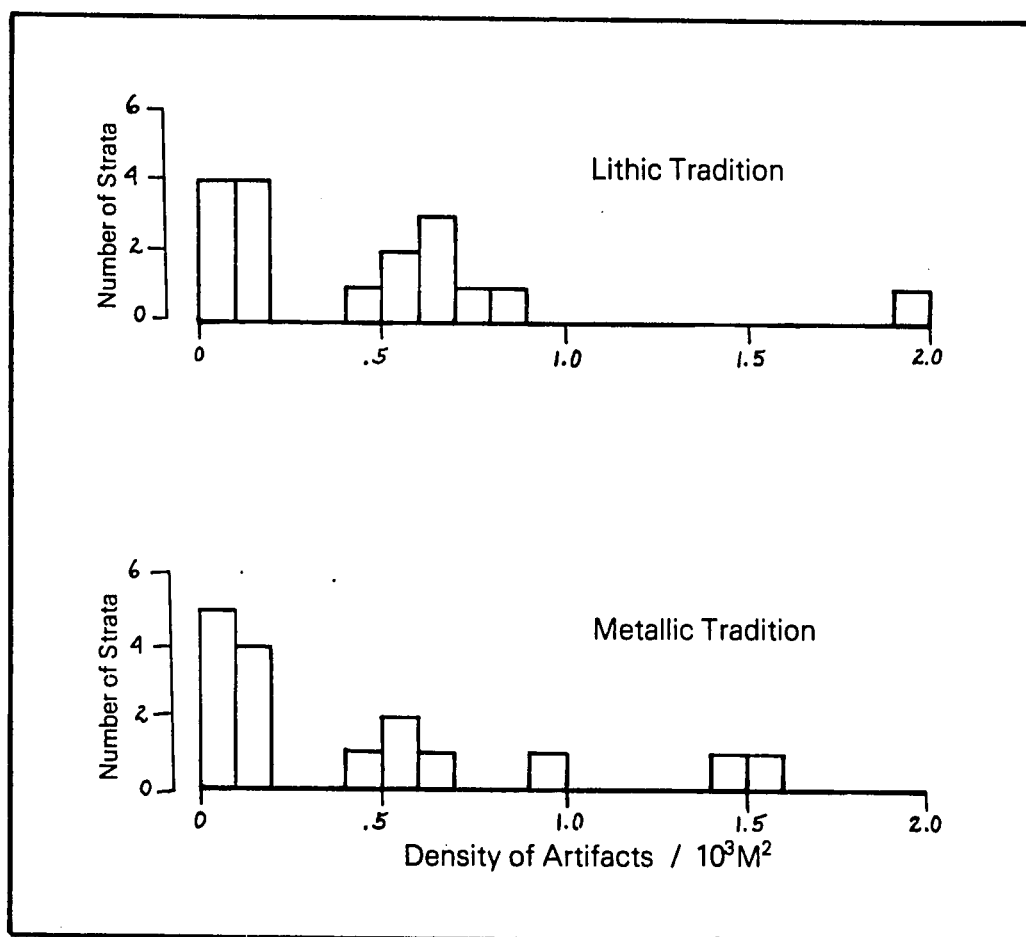


Figure 23. Graphic representation of isolated artifact densities for various strata, showing concentration of values below 0.02 and above the mean of 0.43.

degree of similarity is the first indication that the land use strategies of the two traditions might be strongly similar.

Differential Utilization

Differential utilization among habitats was studied through a visual and statistical comparison of functional type frequencies coupled with a consideration of the differential distributions of isolated features (Dancey, 1973, 1975; Dunnell and Dancey, 1981). Comparison of functional type frequencies took the form of percentage histogram comparison and average linkage cluster analysis. Isolated features were so rare that mere inspection of type frequencies was sufficient for an understanding of their distributions. The results of the analyses for each tradition are presented below.

Lithic Tradition

Eight functional types of tools and two types of features were the basis of comparison for Lithic Tradition land use in the eight habitats. Tool types included 1, 2, 3/5, 4/6, 8, 9, 10 and 13. Types 7, 11 and 12 were absent in all cases, and 3/5 and 4/6 were combined in order to reduce effects of random variation in type frequencies that result from small sample sizes (Chapter 5).

The largest sample size for Lithic habitats, expressed as tools per microenvironmental stratum, is 30 tools; the smallest, 5 (Table 38).

Percentage histograms for the eight microenvironments (Figure 24) develop an initial idea of the similarities in tool type frequencies, but differences among the microenvironments appear to be more clinal than disjunct. Strata IVc and V appear to be most similar, with very high frequencies of Type 13 (projectile points) and much lower secondary frequencies of Types 1 and 4/6. Stratum IVb follows this same pattern, but the projectile point frequency is lower there and other types are proportionately more abundant. This trend continues in Stratum XIV and in Strata I and XIII Type 13

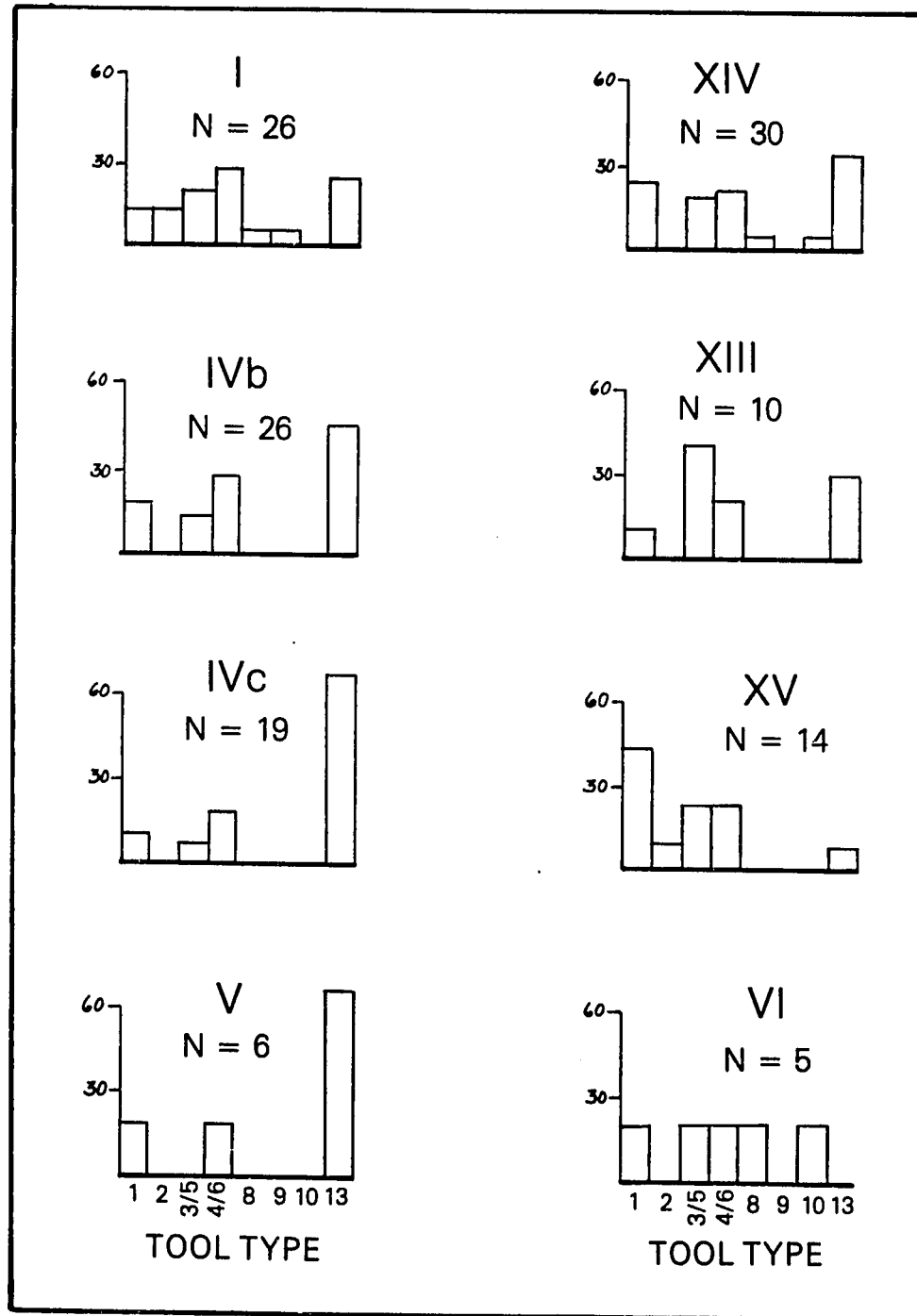


Figure 24. Percentage histograms of isolated lithic tools from the eight habitats.

has become secondary to Type 3/5 (XIII) or Type 4/6 (I). Stratum XV, with a high Type 1 frequency and low Type 13 frequency, and Stratum VI, with no clear predominance of any type and the absence of Type 13 are clearly distinct from the other six microenvironments.

Table 38. Lithic Tool Type Frequencies Among Isolated Artifacts Found in the Eight Habitats*

Stratum	Tool Type								Total
	1	2	3/5	4/6	8	9	10	13	
I	3	3	5	7	1	1		6	26
IVb	4		3	7				12	26
IVc	2		1	3				13	19
V	1			1				4	6
VI	1		1	1	1		1		5
XIII	1		4	2				3	10
XIV	7		5	6	1		1	10	30
XV	6	1	3	3				1	14
Total	25	4	22	30	3	1	2	49	136
Percent	18	3	16	22	2	1	2	36	100

*Tool types 3 and 5 and 4 and 6 are combined to reduce random variation caused by small sample sizes.

To distinguish among the six microenvironments which do not show clear distinctions among themselves, I conducted a cluster analysis based on Brainerd-Robinson coefficients, calculated from the values displayed in Table 38. Microenvironment XV was included in this analysis to confirm its difference from other units; but VI was excluded because of its clear distinction and because most

functionally relevant artifacts from that environment are features, not discrete objects. Figure 25 presents the results.

Breaking the dendrogram at the largest line between linkages in each branch, three distinct clusters result, consisting of microenvironments IVc and V; IVb, XIV, I and XIII, XIII and XV. I shall refer hereafter to these three groups as Habitat Types LA, LB and LC. Microenvironment VI is Habitat Type LD. A reinspection of Table 37 indicates that microenvironments comprising Habitat Type LB are clustered apart from microenvironments V and IVc because of relatively lower frequencies of Type 13 and higher frequencies of 1, 3/5 and 4/6 than are present in LA, where projectile points predominate. Projectile points are a minor component of the assemblage in microenvironment XV. Only 11 isolated features could be attributed with confidence to the Lithic Tradition. Seven of these were small pits dug in ridges, primarily near the ends of ridge formations, and four were cairns, found either on ridges or the ridge-like upper edges of terrace escarpments (Table 39). Cairns in all cases appeared to mark important environmental features. Two were situated at outcrops of lithic material; the others marked a stream confluence where numerous occupations were present. The presence of pits distinguishes Stratum VI (ridges), from all other microenvironments. There, pits outnumber all other functional classes of artifacts, comprising 50 percent as opposed to cairns (14%) and all classes of tools (36%). Thus, the activities associated with pit excavation were the most commonly performed in this habitat.

We have four habitat types; LA, where projectile points are nearly the only type present; LB, where projectile points are common, but Types 1, 4/6 and/or 3/5 are also abundant; LC, with a preponderance of Type 1 and few projectile points, and LD, in which the most common functionally meaningful artifact is the small pit and where no other type is present in any frequency.

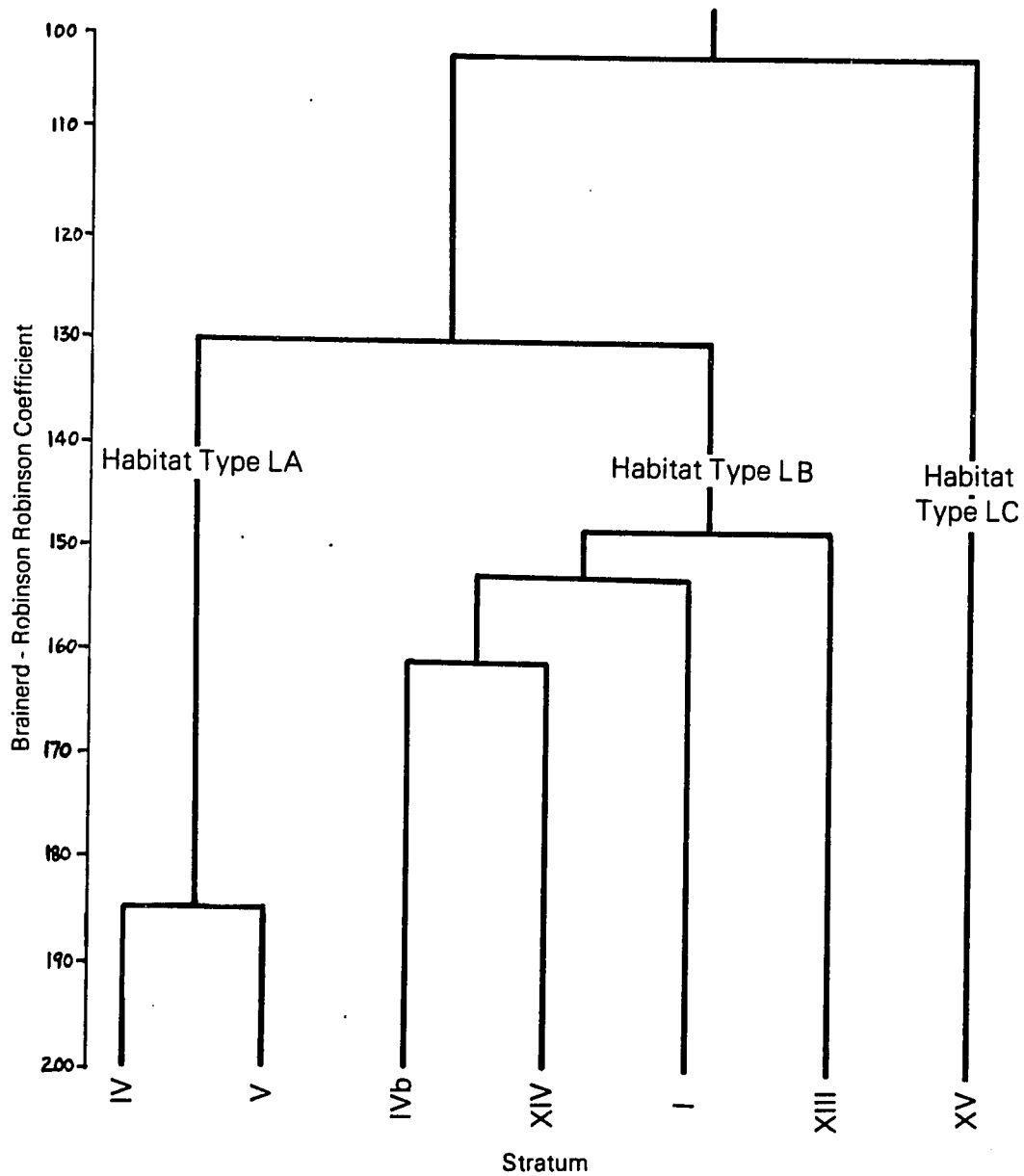


Figure 25. Clustering of microenvironmental strata into Habitat Types on the basis of tool type frequencies and therefore, by activity distribution. Dendrogram produced by average linkage cluster analysis.

Table 39. The Environmental Distribution of Features,
Excluding Fences and Roads, Attributable to Both Cultural Traditions

Stratum	Kind of Feature						
	pit		cairn		ditch	plowed field	salt lick
	L*	M*	L	M	M	M	M
III					2*		
IVb			1	1	1		
V			1	1			1
VI	7		2				
XIII				1			
XIV					3	1	
XV					2		
Total	7		4	3	8	1	1

*Lithic Tradition

*Metallic Tradition

*Ditches extend from stratum I or XIV across strata IVb, IVc, III and XV. The total number of separate ditches is not over 3. Numbers in the ditch column refer only to the instances where ditches were encountered in sample transects.

Metallic Tradition

The same procedure was used to identify various habitat types among the seven heavily utilized microenvironments of the Metallic Tradition, with much more clearcut results. Initial comparison, in this case, was made using the eleven functional types of containers, cartridges and fishing implements (Table 40). Again, to partially reduce the effects of small sample size, two low-frequency types, container Types M4 and M6 have been combined (This places M4 in the "Other" category.). Only six of the microenvironments contained enough of these types for valid comparison. The few functional type denotata present in Stratum V indicate a predominance of Type M10 cartridges, and in that respect, Stratum V resembles Strata IVc and VI.

Table 40. Distribution of Metallic Tradition Functional Types Among Isolated Finds From the Seven Habitats

Stratum	Functional Type									Total
	M1	M2	M3	M4/6	M5	M8	M9	M10	M11	
I	2						8			10
II		1					9	1		11
IVc	1	3		1	1		3	14		23
V					1			2		3
VI		2						16		18
XIII	5	5	1	3		1		1		16
XIV	4	7				1	4	1	1	18
Total	12	18	1	4	2	2	24	35	1	98
Percent	12	18	1	4	2	2	24	36	1	100

Percentage histograms of the remaining six microenvironments (Figure 26) are readily placed into three groups; Strata I and II in which cartridge Type M9 represents over 80 percent; IVc and VI with a prevalence of cartridge Type M10 and a secondary, much lower frequency of container M2; and XIII and XIV where M1 and M2, in fact, containers in general, are far more abundant than cartridges. Average linkage cluster analysis based on Brainerd-Robinson coefficients of similarity confirms this grouping (Figure 27). The three groups will be identified as Habitat Types MA, MB and MC, respectively. Because of its similarity to IVc and VI, micro-environment V is included in MB.

Although habitats of the two traditions are much the same, the patterns of utilization among those microenvironments are quite dissimilar and distinct land use strategies are indicated.

Differential utilization is reflected by the kinds of features in the Metallic Tradition and their distributions (Table 39). Roadways and fences, not included in the table are present in all microenvironments, traversing them. They showed no tendency to concentrate anywhere. Cairns are still present in the terrace escarpment and environments, but one is also present along a stream in Stratum XIII. Cairns in all cases mark major occupation units or road intersections.

All other features are related in some way to plant or animal husbandry. Ditches, which traverse many environments of the open plain began along streams and all three observed ditches terminate at the plowed field in Transect G1. The only other feature present is a salt lick within a rubber tire, around which were numerous hoofprints of domestic cattle (Bos taurus). Features do not represent differential utilization to any great degree, but strongly indicate the nature of Metallic Tradition resource utilization, which is discussed further in Chapter 8.

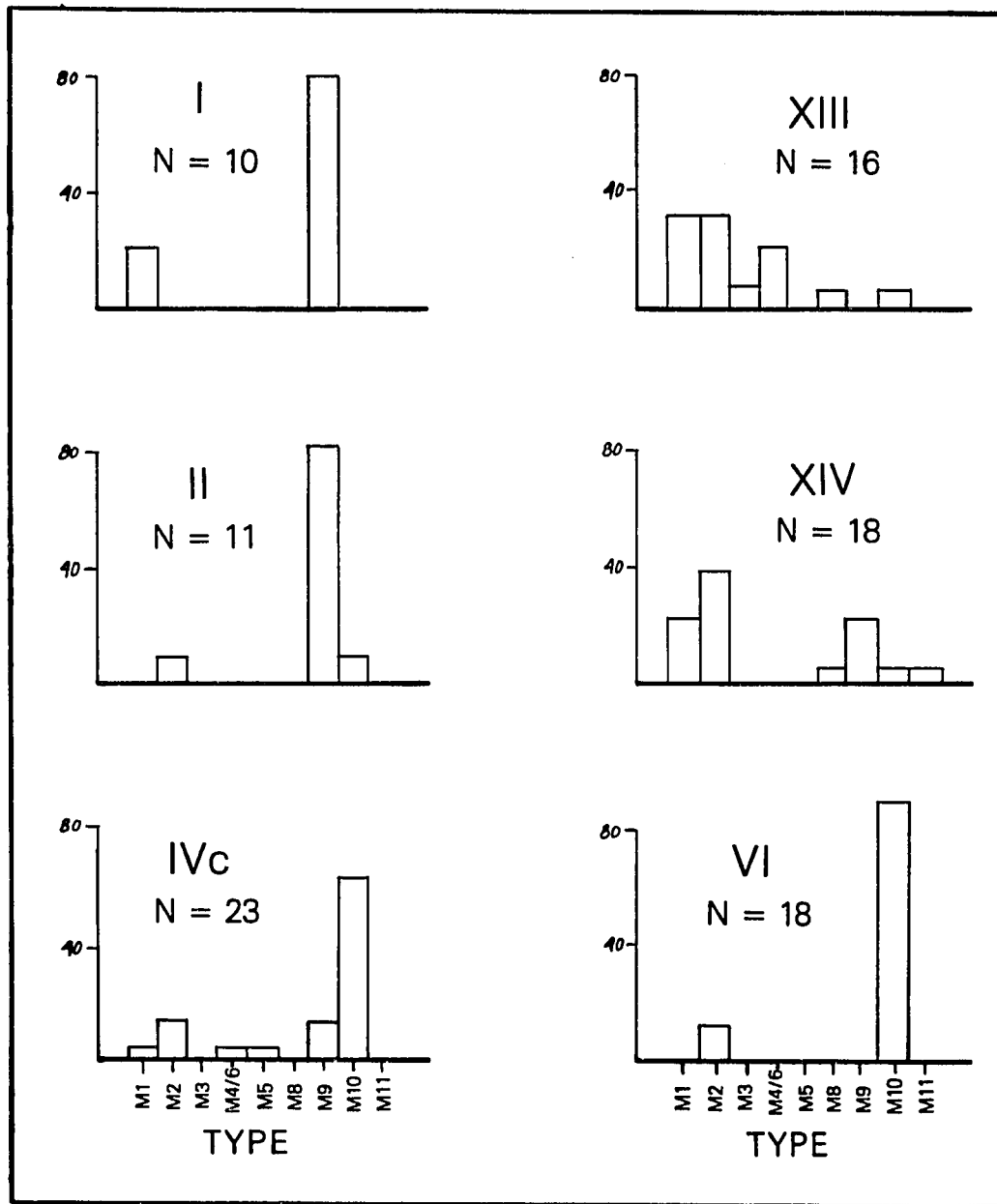


Figure 26. Percentage histograms of six of the microenvironmental strata, based on Metallic Tradition functional types. Note the three pairs of microenvironments with nearly identical type distributions.

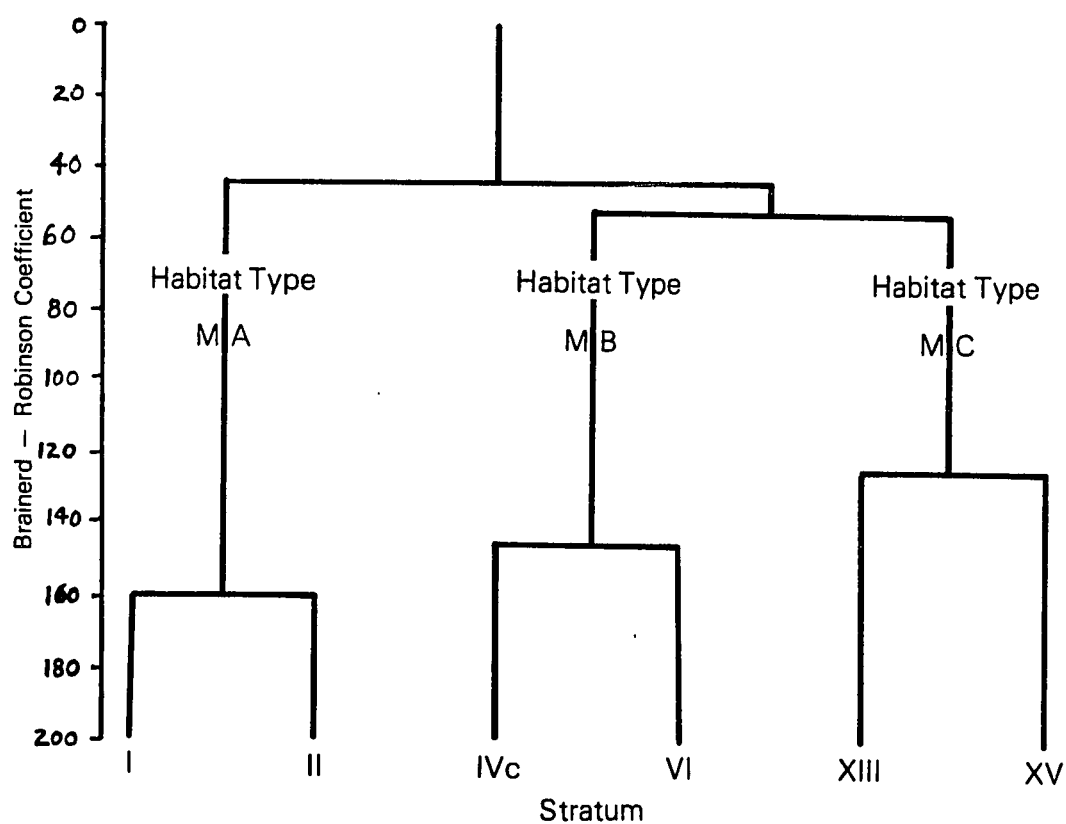


Figure 27. Dendrogram based on average linkage cluster analysis of isolated Metallic Tradition artifacts from six of seven habitats.

Changing Patterns of Land Use

The study of change in land use patterns requires the addition of the temporal dimension to the analysis of artifact distributions. This poses technical problems which are not readily overcome, in that many of the isolated artifacts, particularly those representing the Lithic Tradition, cannot be dated. In fact, of the 10 Lithic and 11 Metallic functional types, chronologies can be developed for only 5: Lithic Type 13 (projectile points), and Metallic container Types M1 and M2 and cartridge Types M9 and M10. In addition, on the basis of infilling and soil development, approximate ages for ridge pits have also been proposed and dates have been obtained or can be assumed for irrigation ditches, the plowed field, fences and the salt lick. With respect to the Metallic Tradition, however, the dating problem is minor. Even though only 36 percent of functional types of discrete objects can be dated, denotata of these types represent 90 percent of Metallic Tradition isolates. The majority of features (5 of 8 plus two fences) can also be dated. Therefore, change in land use patterns can be discerned with a high degree of confidence.

On the other hand, problems of dating can potentially be a severe impediment to understanding change in Lithic Tradition land use. Only two classes of artifacts can be dated and one of these (pits), only tentatively. I might assume, as others have done (cf. Dancey, 1973; Thomas, 1971), that the dates ascribable to projectile points found in various microenvironments are also referable to all other artifacts from those areas, but such an assumption may be fallacious. Unlike the Priest Rapids area (Dancey, 1973) and Reese River Valley (Thomas, 1971), in which nearly all projectile points belonged to a relatively brief span of time which other investigations had shown to include a single adaptive strategy, isolated projectile points from the Pahsimeroi Valley, like the associated occupations, date from 8000 to 100 BP, with no tendency to be concentrated during any one time period. Some change in patterns of land utilization is likely to have occurred over eight millennia.

It is also possible that some forms of land utilization did not entail the use of projectile points at all. Certainly the absence of projectile points in Settlement Types F, J, L and M attests to this fact. Therefore, dating all activity on the basis of distributions of artifacts representing only one or two activities would beg the question of change.

Fortunately, the problem is not so profound as it may seem at first, again because of the overall numerical dominance of projectile points among tool types and pits among features (Tables 38, 39). Thirty-six percent of tools are projectile points, a value 1.5 times that for any other individual tool type. Pits are 64 percent of features. Taken together, these two categories are nearly two-fifths of the total. Although the two types represent a minority of the kinds of activities performed, they comprise a superior majority of all individual episodes of activity performance. Because of the dating problem, however, the study of changing land use will be confined to the single activity represented by projectile points (older pits might be filled in by erosional processes, leaving this feature biased toward more recent time periods and making it unsuitable as a means for studying change in land use). Because of the multitude of finds associating this tool type with the killing of animals and people, that single kind of activity is safely assumed to represent hunting and/or warfare. Presuming warfare to be relatively much less common, especially among people living at low population densities and simple level of socio-political organization (Steward, 1938), hunting is more likely here.

Lithic Tradition: Changing Hunting Patterns

Although most projectile points were fragmentary, it was still possible to assign the majority (32 of 48) to one or at least a closely related set of historic types (Table 41). Of three projectile points found outside habitats, none were complete enough for identification. Note the complementary distributions among

Historical Types C1, C2, S2, S3, and S2/3 and all other types in the C and S series, with the former occurring almost exclusively in microenvironments XIII and XIV, the latter more common in microenvironments of the open plain (I, IVb, IVc and V). Type U4, represented by only two individuals, is not common enough by itself for any pattern to be perceived.

Table 41. Microenvironmental Distribution of Projectile Point Types*

Stratum	Projectile Point Type												T
	C1	C2	C3	C4	C5	C6	C4/6	S1	S2	S3	S2/3	U4	
I			1	1				2					4
IVb			1	1		1	1	2		1			7
IVc			1	1	1	1	1	2				1	8
V				2		1							3
XIII		1											1
XIV	1	1		1				2	2		1	1	9
Total	1	2	3	6	1	3	2	8	2	1	1	2	32

*Note the nearly mutual exclusion between C1, C2, S2, S3 and most other types.

When we take the probable ages of members of each type into account (Figure 21) it becomes evident that there has been a change in projectile point distributions. C1, C2, S2, S3 and C6 are the most recent types (100 - 1800 BP); C4, C3, C5 and S1 are progressively older.

The significance of this apparent change can be assessed using the Fischer's Exact Test. To perform this test, combined values for early (1300 - 7000) projectile point types are compared against

combined values for late (100 - 1800) types for two sets of microenvironments. Microenvironments of the open plain, I, IVc, V and the terrace escarpments near canyon mouths IVb form the "open plain" set and microenvironments XIV and XIII comprise the "canyon stream" set. In this case, the null hypothesis is that early and late projectile points are equally common in both sets of microenvironments. The contingency table and the probability calculated by Fischer's Exact Test (p) are shown in Table 42.

Table 42. Contingency Table Comparing Temporal and Environmental Distribution of Projectile Points

Environment	Projectile Point Types		Total
	Late	Early	
Open Plain	3	15	18
Canyon Stream	6	4	10
Total	9	19	28

p = 0.4714

The probability for these distributions to occur by chance is 0.4714, high enough that the null hypothesis cannot be rejected. This is not surprising, since the types were devised to have chronological rather than functional meaning.

Although this result seems to indicate that distributions have not changed through time, a more thorough analysis of the projectile points themselves, proves this conclusion false. Reconsidering Table 41, along with Table 26 (type definitions), it can be seen that Historical Types C1, C2 and S2, all narrow necked projectile points, are confined to canyon stream microenvironments. All other historical types, with the exception of S3 and U4, which have no neck width specifications, are broad necked and occur primarily in the open plain.

Projectile point neck width has long been accorded functional meaning by archaeologists. Many authors have assumed that, when a

bimodal distribution of projectile point neck widths is observed, objects falling within the smaller size distribution are arrow points, and that those within the larger size distribution are the blades of atlatl darts (cf. Binford and Papworth, 1963; Corliss, 1972; Forbiss, 1960; Wyckoff, 1964). More recently, Thomas (1978) has given this assumption some credibility using measurements made on ethnographically collected specimens.

Without drawing the analogy equating narrow necked specimens with arrows and broad necked specimens with darts, it is still possible to postulate that narrow necked and broad necked projectile points are functionally distinct. That is, narrow necked projectile points represent a different hunting technology than the similar broad necked specimens. The apparent complementary distribution of narrow and broad necked types in Table 41 certainly appears to support that contention.

Fischer's Exact Test was again used to test the hypothesis that the distribution of broad versus narrow necked projectile points was due to chance. The contingency table (Table 43) following this page is based on actual neck-width measurements rather than on type definition, and in this instance, narrow necked refers to all neck widths less than 9 mm and broad necked is greater than 11 mm (see Figure 28).

This time, the null hypothesis is rejected and an association between projectile point neck width and microenvironment is demonstrated. Evidently, the hunting technology employing broad necked projectile points was most effective in the open plain, whereas that using narrow necked points was only appropriate in the brushy stream bank areas within canyons or a short distance from canyon mouths.

Again adding the temporal perspective (Figure 28), change in the predominance of these alternate hunting technologies can be discerned. For the three time periods between 1300 and 7000 BP, broad necked projectile points are used exclusively and hunting occurs rarely, if at all in the canyon stream environment (3 of 19

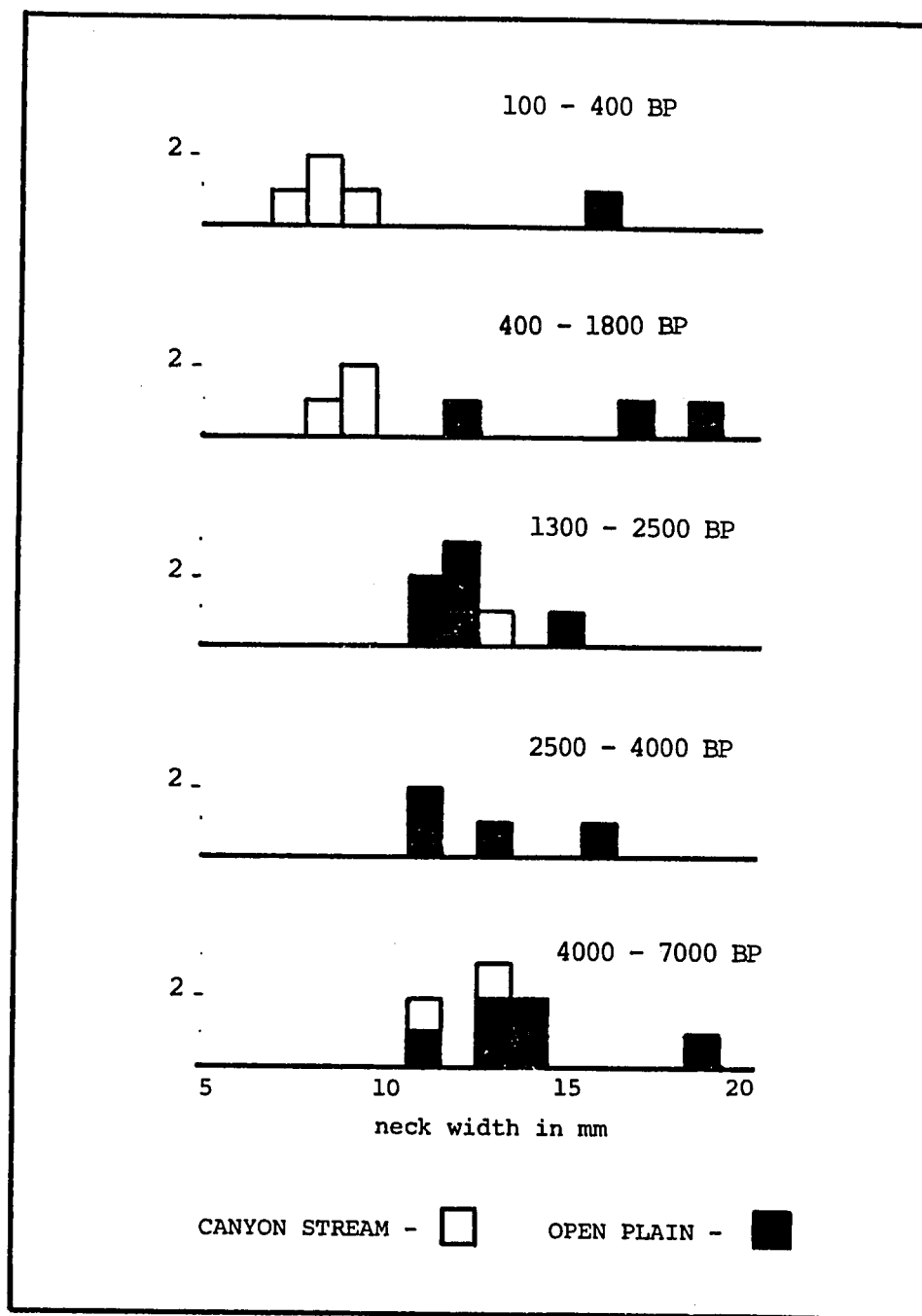


Figure 28. Environmental distributions of projectile points of varying neck width for five time periods of the Lithic Tradition.

classes). Thereafter, in Period 5 (400 - 1800 BP), broad and narrow necked types are in equal proportions, and their environmental distributions are complementary. Finally, during Period 6 (100 - 400 BP), environmental distributions of the two projectile point size categories hold true and it is evident that the technology using broad necked projectile points had by now been almost entirely replaced.

Table 43. Contingency Table Comparing Environmental Position with Projectile Point Neck Width

Environment	Projectile Point Neck Width		Total	
	Broad	Narrow		
Open Plain	20	0	20	
Canyon Stream	3	6	9	p = .00018
Total	23	6	29	

Potential for age bias. Canyon stream microenvironments are both nearer the heads of drainage basins than microenvironments of the open plain and are closer to steep, relatively unstable canyon walls and mountainsides. Therefore, the possibility exists that alluvial and colluvial deposition have occurred more recently in the canyon stream areas, and that the observed distribution of projectile points reflects merely differential age of land surface. Because this possibility was anticipated during the data collection phase of research, field notes provide sufficient data for a comparison of this hypothesis with its converse; that differential age is not a significant factor.

Data on soil development, lichen growth and cryogenic soil features show that there are no essential differences between surfaces in the two kinds of environments. Both have moderately developed aridisols, exhibit equivalent degrees of lichen development

on exposed boulders and cobbles, and contain patterned ground features. According to Fosberg (1965) who studied the structure of patterned ground features in Idaho soils, these features are periglacial in origin and date no later than the terminal Wisconsin. Only in a narrow strip of land along streams in both canyons and the open plain is recent alluvium observable, and these active floodplains were not studied (see Chapter 4). It is thus safe to conclude that all studied surfaces are Pleistocene in age, and that the differential distribution of broad versus narrow necked projectile points is real and not the result of age bias.

Changes in Metallic Tradition Land Use

The environmental distributions of historic classes among four Metallic Tradition functional types (M1, M2, M9 and M10, Table 44) show no significant changes, and in only one instance is a noteworthy difference in distributions observable. M1 cans are rare in all habitats except MC, the canyon stream habitat. M2 cans, not a common part of the Metallic Tradition before +2 BP occur in Habitats MB and MC throughout their history, and M10 cartridges always predominate in the ridge and open terrace habitats (MB). M9 is the only functional class showing any difference. Although the type is most common in the open plain environments near streams (Habitat MA), the oldest cartridges of this type occur most often in the canyon stream habitat of MC. This difference is interesting and may represent a change in the environments in which cartridge Type M9 was used. However, the numbers are so small that no conclusion to that effect is warranted.

The land use strategy of Metallic Tradition people entailed the differential utilization of three types of habitat. The open plain near-stream microenvironments (Strata I and II), constituting Habitat Type MA were exploited through activities, readily identified as hunting activities, using almost exclusively the M9 type of cartridge (known to us practitioners of the Metallic Tradition as shotgun shells). Activity conducted in the ridge and open terrace

microenvironments of Habitat MB revolved around the use of M10 cartridges, again reflecting a different kind of hunting technology from that employed in Habitat Type MA (M10 cartridges are known by our folk classification as rifle shells). Finally, containers, particularly those having held solid foods (M1) and beverages (M2) dominate the artifact inventory of the canyon stream habitat and indicate consumption, rather than resource acquisition activity. True, this environment alone contains M8 cartridges (22 shells) and Type M11 (fishing implements), but the rarity of these types argues against any conclusion that the activities associated with them were of major importance.

Table 44. Distributions of Historic Types of Metallic Tradition Artifacts Among the Three Habitat Types*

Habitat Type	M1 Cans			M2 Cans		M9 Cart			M10 Cart		Total
	U1	U2	R2	S	A	Pd	Pa	Pl	NG	G	
MA		1	1			1	7	9		1	20
MB		1		2	1		2	1	5	17	29
MC	1	5	1	4	2	2	2			2	19
Total	1	7	2	6	3	3	11	10	5	20	68

*Note that there are few differences that cannot be attributed to sampling error.

Intensity of Use

The kinds of activities represented by isolated discrete objects do not change, but the intensity with which they were performed appears to have increased substantially. Artifact chronologies developed in Chapter 6 place unridged M9 cartridges, corroded M10 cartridges with almost totally deteriorated paper and double-lid solder-sealed M1 cans into the period beginning after 80 BP and ending during the early years of occupations F1P1/F2B. The date of

20 - 30 BP is probably appropriate, and I shall use 30 BP here, to be conservative. Given the total number of isolates in these three classes (9), the deposition rate for the 50 year period during which the artifacts accumulated would be 0.18 artifacts per year. For the following 55 year period, 50 artifacts in these three classes were recovered, giving a minimum deposition rate of 0.91. If the earliest confirmed Metallic Tradition date of 46 BP is taken as the start of the earlier period, 9 artifacts recovered in 16 years is a rate of 0.56 artifacts per year, and an increase in activity in later years is still indicated, although the change is not so great. Clearly, those uses of Habitat Types MA, MB and MC which led to the deposition of isolated artifact Types M1, M2, M9 and M10 were intensified in the later half-century.

Features and domestic fauna: Kind and density. The general increase in the intensity of Metallic Tradition activity is contradicted by data on features and domestic fauna. Among isolated features, only two, one fence and the tire salt lick date later than 17 BP. The plowed field in Tract G1 and by extension, the three irrigation ditches that once watered it, and at least one fence pre-date 17 BP.

Domestic fauna also show a marked decrease in deposition rate. Isolated bones of domestic mammals were placed in three weathering classes; Weathering Class 1, +10 - +25 BP; Class 2, 20 - +10 BP and Class 3, >20 BP (Chapter 6).

The numbers of isolated faunal units (isolated bones and skeletons) for each domestic species are presented in Table 45. Nine faunal units belong to Class 3, only five to Classes 1 and 2 combined. Again considering deposition rates for the periods 80 - 20 BP and 20 - +25 BP, the rates of faunal deposition are .15 and .11 respectively. If the onset of the Metallic Tradition is taken as 46 BP, the earliest date for which I have firm evidence, rates are 0.35 versus 0.11 faunal units per year. Decrease is indicated in both cases.

Taken together, features and faunal remains both show a decrease in activities associated with animal husbandry and in animal populations (or at least in situ death rates) from the first to the second half century of the Metallic Tradition.

Table 45. Remains of Domestic Mammals Found as Isolated Individuals, Listed According to Weathering Class*

Weathering Class	Age	Taxon			Total
		<u>Bos</u>	<u>Ovis aries</u>	<u>Equus caballus</u>	
1	+10-+25 BP	3			3
2	20-+10 BP	2			2
3	> 20 BP	3	2	4	9
Total		8	2	4	14

*Elapsed time since death

When early and late Metallic Tradition periods are compared in terms of isolated domestic fauna versus other isolated discrete objects (Table 46), the differences are significant ($\chi^2 = 14.290$, $p < .001$).

As interesting as the overall decrease in animal husbandry is the change in species hunched. During the period preceding 20 BP, horses (Equus caballus) and domestic sheep (Ovis aries) were present along with cattle (Bos taurus). After 20 BP, sheep and horses are absent.

Summary. The overall picture shows cartridge using activities (hunting) and isolated can consuming activities increasing after 20 - 30 BP while the husbandry of domestic plants and animals and the numbers of domestic animals being used, decrease markedly. These changes are coincident with an overall shift in settlement pattern, as will be shown below.

Table 46. contingency Table Comparing Numbers of Faunal Units and Discrete Objects Attributable to the Two Periods Before and After 20 BP

	Artifacts	Faunal Units	Total	
20 to +25 BP	50	9	55	$\chi^2 = 14.290$ $p = .0000021$
before 20 BP	9	9	18	
Total	59	14		

Settlement Patterns

Settlement patterns for each of the ten time periods were defined through observation of the microenvironmental distribution of settlements. Tables 47 and 48 list the numbers of each settlement type attributable to each time period and Figures 29 and 30 illustrate the temporal and environmental distributions of settlement types. Change in settlement pattern is discernible as difference in the kinds and distributions of settlement types between consecutive periods. In this section, I first describe settlement patterns, then discuss overall trends in settlement pattern change for each cultural tradition.

Lithic Tradition Settlement Patterns

You will recall from Chapter 5 that 13 Lithic Tradition settlement types were discerned (Types A, B, D, F, G1, G2, H, I, J, K, L, M and R), and that these were grouped for descriptive purposes by size, feature and tool type distributions into three sets: domestic settlements (Types, A, B, G1 and G2); large non-domestic settlements (Types D and F), and small, non-domestic settlements (H, I, J, K, L, M and R). Because dating was based largely on the projectile point chronology and many occupations lacked this class of tool, not all members of all settlement types could be dated and, in some cases,

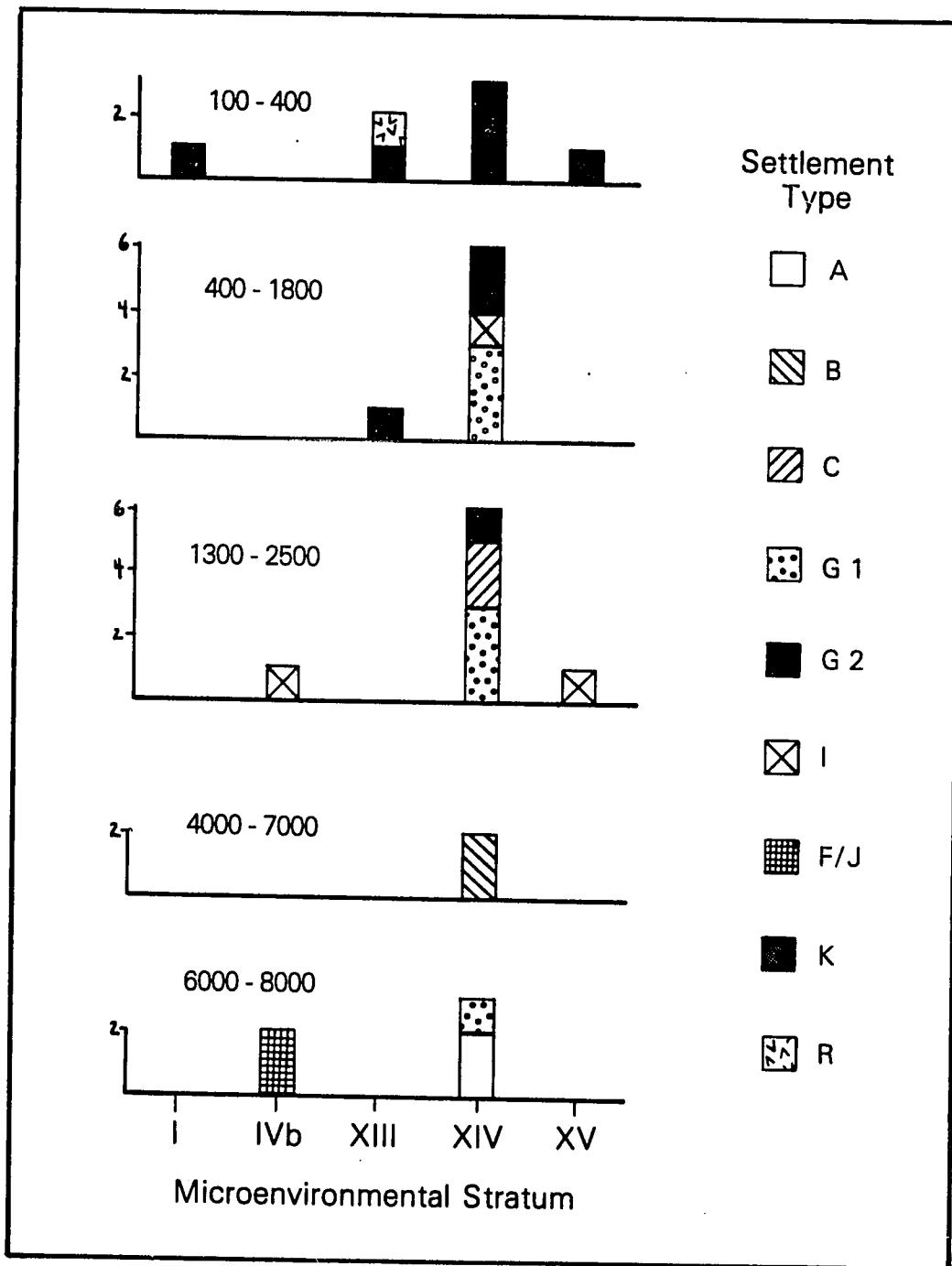


Figure 29. Graphic representation of Lithic Tradition settlement patterns during five periods. The 4000-2500 year period is not included because it exhibits no pattern, consisting of a single occupation of Type H.

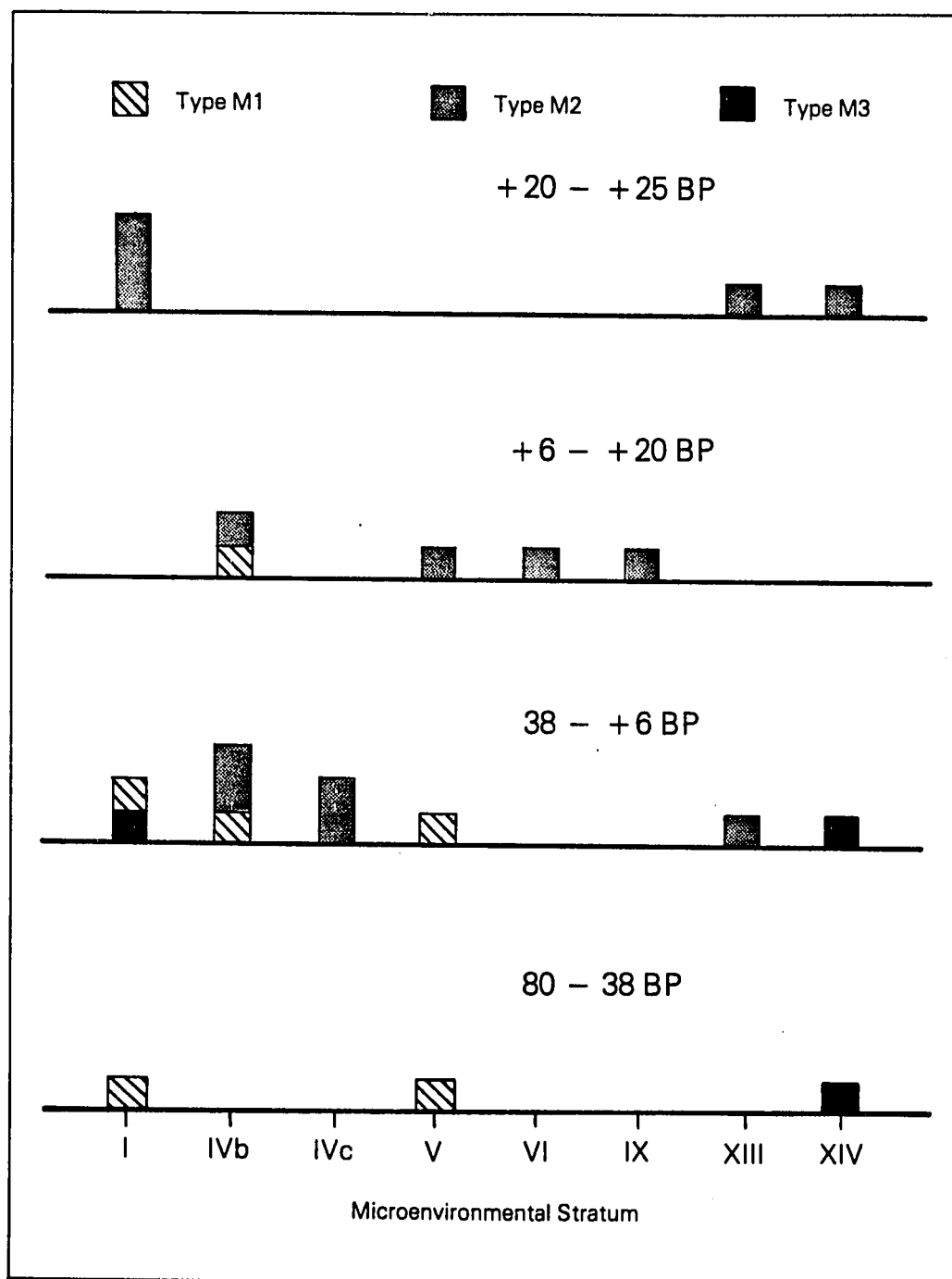


Figure 30. Microenvironmental distribution of settlements during four periods in the Metallic Tradition.

ages could not be assigned to any members of a type (Types F, L and M; only 1 member of Type H could be dated). Consequently, it must be understood that settlement patterns are defined on the basis of dated settlements only. Although undated settlement types may have been important aspects of settlement pattern change, that significance remains unrecognized.

Lithic Tradition settlement patterns are defined for each period on the basis of data presented in Table 47 and Figure 29, as follows.

Table 47. Temporal Distribution of Ten Lithic Tradition Settlement Types

Age	Settlement Type									
	A	B	D	G1	G2	F/J	H	I	K	R
100-400					4				2	(1)*
400-1800				3	1			1+	2	
1300-2500			2	3				2+	1	
2500-4500							1			
4000-7000		2								
6000-8000	2			1		2				

*Artifact used to date occupation D6B was a delicate, triangular projectile point blade fragment of the form and flaking pattern common to Types S2 and S3; however, because of its fragmentary condition, the artifact cannot be placed any closer than C1, C2, S2, S3 and this occupation spans the 1800 - 100 year period. It's placement in 100 - 400 is most probable.

Period 1: 6000 - 8000 BP. Three domestic and two non-domestic occupations belong to this period. All domestic occupations (2 of Type A, 1 of Type G1) occur in microenvironment XIV, adjacent to streams less than 2 km below canyon mouths. Both non-domestic settlements belong to Type J and are in the terrace escarpment microenvironment, also less than 2 km below canyon mouths (IVb). In sum, datable settlements belonging to this period are limited in

kind and are spatially restricted to environments a short distance from canyon mouths. When the actual locations of Type J settlements are taken into account, it is evident that all Period 1 settlements are also situated less than 200 m from permanent water sources.

Period 2: 4000 - 7000 BP. Very few settlements (2) belong to this time period, and both are domestic Type B, situated in micro-environment XIV. No non-domestic settlements are assignable to Period 2. If this small sample can be construed as exhibiting a pattern, it is a highly restricted one. However, given the small sample of Period 2 settlements and the difficulty experienced in dating some types of settlements, this restriction may merely be the consequence of sampling error and/or dating problems.

Period 3: 4000 - 2500 BP. The restriction in settlement type that began in Period 2 culminates in this time period. Only one settlement, the single, dated example of Type H can be assigned to Period 3. Again, microenvironment XIV is the location of this settlement.

Period 4: 2500 - 1300 BP. This period is characterized by a sharp rise in the number and diversity of settlements. More settlements are assignable to this period than any other, and settlement-type diversity is equalled only in the following Period 5. As with previous periods, domestic settlements, now all of Type G1, are confined to streams below canyon mouths (XIV). A second large settlement type, non-domestic Type D is also present in that micro-environment as is a single member of Type K, which strongly resembles D (see Tables 16, 17). A third new, non-domestic settlement now appears. Type I is a functionally complex settlement type which, in this instance, occurs in microenvironments XV and IVb.

Again, a closer look at the actual locations of Type I settlements reveals that they are both within 200 m of water. Although

settlements are now more diversified, they remain environmentally restricted to the areas near water and within 2 km below canyon mouths.

Period 5: 1800 - 400 BP. With two exceptions, the settlement patterns of this period are identical to Period 4. Domestic settlement Type G1, and non-domestic settlement Types K and I are still situated under 2 km from canyon mouths not far from water. The only differences are that large non-domestic D-type settlements are absent and a new domestic settlement type, G2 appears in a heretofore unused microenvironment, the canyon bottom, near a stream (Stratum XIII). Significantly this is the first dated settlement type to occur outside the canyon mouth environments and, as will be discussed more extensively below, represents the onset of increased activity in the canyon-stream habitat.

Period 6: 400 - 100 BP. Settlement patterns change markedly from previous periods in several respects. First, nearly half (43%) of settlements are found outside the canyon mouth habitat, with 28 percent being found inside the canyons themselves. Second, the complex non-domestic settlement Type I is absent and a new, unique settlement, R, occurs; third, settlements of Type K are present both in the canyon mouth area (70 m from water in this instance) and along a stream in the open plain (microenvironment I). This is the first occurrence of a dated settlement in microenvironment I, but this novelty should not be overrated because only a single settlement is represented.

Finally and most significantly, all domestic settlements are now of the small Type G2 and are not only in the canyon environment, as in Period 5, but occur now in numbers in the situation previously occupied by Type G1, the canyon mouth, streamside microenvironment XIV.

Discussion: Changes in settlement pattern. The following discussion of change in Lithic Tradition settlement patterns concentrates on three general topics: (1) the overall micro-environmental distribution of all settlements, (2) the change in kinds and distributions of non-domestic settlement types, and (3) shifts in environmental distribution, tool type frequencies and sizes of domestic settlement types.

There is a strong degree of continuity in the overall environmental distribution of settlements throughout the Lithic Tradition, a continuity which is broken only within the last 1800 years. From the onset of human habitation, as much as 8000 years ago, to the middle of Period 5 (ca. 1300 BP), settlements of all dated types occur only in open plain microenvironments near canyon mouths (IVb, XIV, XV). Certain types of settlements, specifically domestic settlement Types A, B and G1 and D-type non-domestic settlements occur only in XIV, while small non-domestic settlements often occur farther from water in microenvironments XV and IVb. Beginning in Period 5 this pattern changes with one settlement present along a canyon stream (XIII). By Period 6, nearly half of all settlements are in microenvironments XIII and I, away from the canyon mouths.

This difference in distribution is significant. In all, the number of settlements present in the canyon mouth microenvironments before Period 5 is 15; none occur elsewhere. Then settlements occur in those same microenvironments during Periods 5 and 6 with four settlements present in other areas, primarily within canyons. The probability of these sets of values occurring by chance, calculated by Fischer's Exact Test, is 0.0421. The difference is not attributable to chance. Most settlements outside canyon mouth microenvironments date between 100 and 400 BP, the period during which the greatest number of settlement pattern changes occurs.

Significant change also occurs among non-domestic settlement types, and takes two forms. First, all types of non-domestic settlements have brief, continuous periods of existence. Type J, for example occurs only in Period 1, D only in Period 4, while K is

present continuously from Period 4 on. This pattern indicates change through time either in the kinds of activities performed or in the associations among the activities performed, commonly in the canyon mouth environments.

The overall tendency for temporal variation in non-domestic settlements is punctuated by two broader scale trends.

The first notable trend in non-domestic settlements is the pre-4000 BP absence of non-domestic settlements containing projectile points. Because of the probability that sampling error affects the observed settlement patterns for Period 2, it is only possible to conclude that Period 1 differs from later periods in this regard. The settlement pattern of Period 1 clearly represents an adaptation different from that observed for periods later than 2500 BP.

The second notable trend is a general absence of non-domestic settlements during Period 2 and the rarity of all settlement types during Period 3. The paucity of non-domestic settlements in this 4500 year span, as previously mentioned, may be due to sampling error, but the generally low frequency of all settlements attributable to the period is noteworthy and may reflect a low intensity of human occupation. The hypothesis that the Project Area was rarely occupied from 6000 - 7000 BP to 2500 BP can be tested. If people had rarely been present in the area, one might expect to find fewer isolated projectile points from this period than from other periods, all other things being equal. If the number of Period 2 and 3 projectile points is greater than or equal to that of other periods, the converse is the more probable hypothesis.

Twelve isolated projectile points are attributable to the 4500 year Periods 2 and 3, compared to eighteen for Periods 4 - 6 (2500 years), and two from Period 1 (2000 years). Converted to deposition rates, .72/century during Periods 2 and 3 and .10/century in Period 1, these figures indicate a gradual increase in occupation intensity over time. However, all other things are not equal.

Two additional variables may be involved: age bias in artifact recovery, and a change in the nature of activity in the Project

Area. The first of these already has been dismissed as inappropriate: there is no evidence that surfaces vary significantly in age; all are pre-Holocene. Change in the nature of human adaptation is certainly a factor, as already noted. The Period 1 settlement pattern is unique, and the low rate of projectile point deposition is probably another reflection of a differing mode of adaptation. The impossibility of comparing settlement pattern changes between Periods 2 and 3 and other periods also has already been discussed; the sample is simply too small.

However, if in the absence of contrary evidence we assume that settlement differences between Periods 2 and 3 and later periods are due merely to sampling error, then the hypothesis that the intensity of human use increased after 2500 BP is supported. The intensity of activity during the last three periods combined is three times that of the preceding time interval.

Two forms of change can also be seen in the content, distribution and size of domestic settlement types, one apparently representing variation in ways of performing the same sorts of activities, the other indicative of major changes in adaptive strategy. Minor variations appear in the form of gradual, minor changes in tool types frequencies. All domestic-type settlements are similar in the numbers and types of tools present (minimum mean similarity = 125). With the exception of occupation A1U (Type G1), which occurs in Period 1, domestic settlement types A, B and G occur for continuous periods. There are two, equally plausible minor changes occurring over time: (1) it is drift taking the form of small scale variations in the way domestic tasks are performed, or (2) temporally proportional increases in the degree of mechanical weathering.

People were apparently doing similar kinds of things in all domestic settlements throughout the Lithic Tradition, but the habitat in which they did these things and the numbers of people involved appear to have changed rather suddenly between 1300 and 400 BP. Somewhere during that interval, the sizes of domestic

settlements and, in some instances, their locations, change. Settlements become much smaller and they occasionally appear within canyons as well as below canyon mouths.

The size change is demonstrably significant. Settlement Type G2, the small sized version of Type G appears first as one of four domestic settlements in Period 5, and itself, dates between 1300 and 400 BP. In the subsequent Period 6, all domestic settlements are Type G2. According to Fischer's Exact Test, the probability that these changes in numbers of settlement Types G1 and G2 would occur by chance alone is 0.071. The import of this change in settlement size is most evident when the mean areas of domestic settlements are considered for all time periods. They are: Period 1, 783 square meters; Period 2, 850; Period 3, none; Period 4, 903; Period 5, 700; and Period 6, 242 (for range see Tables 12, 13, 16). Period 6 domestic settlements are about one-third the size of all previous periods. If the one G2 type settlement is removed from the Period 5 population, the mean for that period is 850 square meters. The size decrease is indeed abrupt. A t test for the difference between sample means (Thomas, 1976:235-240) comparing the mean of all domestic settlements of Period 5 against Period 6 shows the change in settlement size to be significant at the .05 level ($t = 2.78$; t for the .05 level of probability at 6 df = 2.57).

If we accept the notion that settlement area is correlated with the size of the social unit occupying a site (cf. Cook, 1972; Cook and Heizer, 1965; Naroll, 1972; Plog, 1975; Zubrow, 1975), then smaller human groups are occupying Type G2 settlements, groups approximately one-third the size of those occupying G1 settlements. Visits by smaller social units to the Project Area began to occur in Period 5, in the canyon environment. At that time they may have represented satellites of the larger G1-type settlements present below canyon mouths or independent units visiting the area. After 400 BP, all domestic units are small and now occur as definitely independent groups, occupying both canyon bottom and canyon mouth environments. This change in social unit size coincides with the

changing hunting technology discussed under land use and the two events may be closely related.

Metallic Tradition Settlement

Because only three types of dated settlements occur in the Metallic Tradition, there is no need to simplify the discussion of settlement pattern beyond the designations MS1, MS2, and MS3. Recall that MS3 contains permanent wooden structures, which are absent in the other settlement types. Table 48 and Figure 30 present temporal and environmental distributions of settlement types. Settlement patterns for Periods 7 through 10 are:

Table 48. Temporal Distribution of Metallic Tradition Settlement Types

Time Period Years BP	Settlement Type		
	MS1	MS2	MS3
+20 to +25		5	
+ 6 to +20	1	4	
38 to + 6	3	4	2*
38 to 80	2		1*

*One of the total of 2 Type MS3 settlements is the farmstead in transect G, occupied from 46 to 17 BP.

Period 7: 80 - 38 BP. Three settlements are recorded for the period, one of which (a representative of MS3) was not in survey transects, but is included because of its relationship to the plowed-field feature in Transect G1. Only two settlement types are represented, MS1 and MS3. The former occurs in microenvironments I and V, both within 50 m of a stream in the open plain. MS3 is on a stream near a canyon mouth.

Period 8: 38 - +6 BP. The greatest diversity in settlement types is present in this period, which land use data indicates to have been a time of transition or perhaps of diversification in the forms of human adaptation. Two examples of MS3 occur, both near water but at varying distances from canyons. MS1 is still common, and still occurs in I and V plus microenvironment IVb. When this third settlement's actual location is considered, it is evident that all MS1 settlements are within 100 m of water outside canyons.

The third settlement Type MS2 has appeared in high frequency, representing 50 percent of all settlements. MS2 settlements are situated along terrace escarpments with only one located elsewhere, in the canyon stream microenvironment, XIII. During Periods 7 and 8, MS1 settlements are never closer than 4 km from settlements of Type MS3. Although all intervening areas were not inspected by transect, I have walked the stream banks between sampled tracts on many occasions, and have never observed an exception to this rule. MS1, lacking structures, may be a temporary satellite settlement of the more permanent MS3.

In sum, MS1 and MS3 are in the open plain near streams; MS2 is on ridges or terrace escarpments regardless of nearness to water.

Period 9: +6 - +20 BP. Settlement diversity has declined sharply. MS3 has disappeared and MS1 nearly so. Only MS2 remains in numbers and is still found predominantly in ridge and terrace microenvironments of Habitat Type MB.

Period 10: +20 - +25 BP. A complete change in settlement pattern is now evident. MS1 and MS3 are totally absent and MS2 settlements now occur only on streams where they had previously been observed only once, in Period 8.

Discussion: Growing impermanence of settlement. Two major changes are worthy of comment at this juncture: the replacement of MS1 and MS3 with MS2, probably during Period 8, and the change in

habitat of MS2 settlements from the ridge and terrace habitat type to stream habitats in both plain and canyon.

Because of their spatial association and the coincidence of their temporal distributions, MS1 and MS2 form a discrete settlement pattern: large, permanent settlements with buildings and corrals and smaller, temporary settlements over 4 km distant from the main settlements. Between 38 and +6 BP, this settlement pattern is gradually replaced by a new one consisting of tiny, briefly occupied settlements located first in the ridge and terrace habitat (MB) and later shifting to the stream-bank habitats. The change is coincident with a general land use shift from animal husbandry to hunting, and MS1 and MS3 settlements are therefore probably associated with the first form of adaptation; MS2 with the latter. Support for this hypothesis is found in details of land use. The ridge and terrace habitat, where MS2 first occurs is the habitat used almost exclusively for hunting, as is the open stream habitat, where 60 percent of this settlement type occurs in Period 6. Data on biological resource utilization provide further evidence in favor of this conclusion, as I will show in the next chapter.

The total change in MS2 distribution between Periods 9 and 10 is significant ($p = .008$), and represents a major change in settlement pattern. Because no coincident change in land use occurs, there may be no relationship between this event and resource exploitation.

Patterns of Settlement and Land Use: 8000 - +25 BP

Period 1: 8000 - 6000 BP

Land use and settlement concentrate in the canyon mouth habitat, and the presence of small, non-domestic settlements which lack projectile points coincides with the absence of non-domestic settlements with projectile points. The distribution and number of isolated projectile points indicate either a hunting technology differing from that observed for later periods and/or a low

importance of hunting in the adaptation as a whole. Social units inhabiting domestic settlements are large.

Periods 2 and 3: 7000 - 2500 BP

The intensity of human habitation during this long interval is quite low, and the nature of adaptation appears to be highly specialized. Except for one single-activity oriented settlement type (H), only isolated projectile points and domestic settlements can be assigned to this time range. Settlement is still concentrated in the canyon mouth, but hunting activity is oriented toward the open plain habitats. As with the previous period, domestic social units are large.

Period 4: 2500 - 1300 BP

Adaptation has now become more complex. Settlement still concentrates below canyon mouths and hunting technology remains oriented to the open plains, but a marked change is evident in the number and kind of non-domestic settlements. Three kinds are present, all with projectile points. One type (I) is functionally complex, while the other two (K and D) are more specialized and may represent the same or similar kind of activity performed at varying scales. Social units remain large and are, in fact, the largest seen throughout the Lithic Tradition.

Period 5: 1800 - 400 BP

Much like the preceding period, Period 5 differs in important respects. The large, specialized non-domestic settlements are absent, while three innovations occur. Domestic units are still large, overall, but a single small domestic unit occurs for the first time in the canyon habitat. A new hunting technology now supplements the age-old broad-neck-projectile-point-in-open-plain hunting pattern. Narrow neck projectile points now occur and are confined to canyon mouth and canyon bottom habitats.

Period 6: 400 - 100 BP

Radical changes have taken place in hunting technology, habitat, non-domestic settlement type and social unit size. The open plain is all but abandoned in favor of canyon mouth and canyon bottom habitats. The narrow neck projectile point hunting pattern (along streams) has become dominant, and domestic social units are one-third their previous size. Non-domestic settlements are now restricted to highly specialized units reflecting limited activity performance on a small scale.

Period 7: 80 - 38 BP

A new, totally different cultural tradition enters the area, entirely replacing the previous tradition. This first period of the Metallic Tradition is characterized by a settlement pattern including large, permanent settlements and small, temporary satellites, both found along streams in the open plain. Land use is concentrated on cattle, horse and sheep husbandry with one type of hunting along ridges and terraces and another near open, brushy stream channels as minor aspects of the adaptation.

Period 8: 38 - +6 BP

This period of transition first sees an intensification of the Period 7 settlement pattern, with more animal husbandry-oriented settlements (MS1 and MS3) and the artificial enhancement of pasturage through plowing and irrigation. By 20 BP, however, the animal husbandry pattern is giving way to a less permanent adaptation. Of the original three domestic mammals, only cattle remain, irrigation ceases and the abandonment of the large, permanent MS3 settlements begins. A new type of settlement, the small, transient MS2, is beginning to occur in the ridge and terrace habitats and both kinds of hunting activity have intensified.

Period 9: +6 - +20 BP

Animal husbandry continues in the presence of cattle and facilities for their containment (fences) and maintenance (salt lick). However, land use is not predominantly oriented to hunting in open stream and ridge and terrace habitats, with consumptive activity now common in the canyon stream habitats. Nearly all settlements now are the small, MS2 camps and are consistently located on ridges and terraces.

Period 10: +20 - +25 BP

Patterns of the previous period are now fixed, but the location of small temporary camps has shifted to stream banks along water courses. Otherwise, the hunting-oriented adaptation remains.

Causes of Change

The method presented in Chapter 2 for determining the evolutionary relationship between cultural and environmental changes requires, first, that observed cultural changes be related directly to human adaptation. I have already argued that differential distributions of functional classes of artifacts (land use) and occupations (settlement pattern) are the material entailments of activities related to resource acquisition and use and are therefore properly conceived as part of adaptive patterns. Once a change in adaptive patterns is demonstrated, the method proceeds to investigate the second question: is the change related in any plausible way to changes in the resources people acquire or does it represent only a change in the technologies and/or organizations people employ to exploit the same sets of resources.

I have just described many changes in human adaptations to the Pahsimeroi Valley, including: a distinct early adaptation, a low intensity of utilization from 7000 to 2500 years ago, the appearance of a new, more complex adaptive pattern at 2500 BP, the reduction in size of specialized non-domestic settlement types after 1800 BP

and the establishment of a new hunting technology, exploitation of a different habitat and significant reductions in both settlement pattern complexity and social unit size at 400 BP. About 100 years ago the Lithic Tradition is replaced by a completely different tradition that concentrates its adaptation first on permanent settlement and the husbandry of domestic mammals and later gradually turns more toward hunting and temporary settlement.

As interesting as many of these changes are, all of them could not be fully investigated in the context of this study. Although I sought evidence of resource utilization for each time period, I was only able to recover such data for the past 2000 years (Chapter 8). Therefore, it has only been possible to investigate causes for changes occurring between Periods 5 and 10. Of the three changes manifest during this interval (listed previously), I shall address myself to the more complex issues, as follows:

1. The coincident and perhaps closely related changes in habitat, hunting technology, settlement pattern complexity and group size that are perceived at 400 BP.
2. The change in Metallic Tradition adaptations from pastoral to hunting emphasis after 20 BP.

From the perspective of evolutionary human paleoecology, these cases are ideal. To identify natural selection as the ultimate cause of change, variation must exist in the modes of human adaptation which can be differentially transmitted to succeeding generations. Looking at the problem as an hypothesis, if natural selection is the ultimate cause of change, then we should first see alternative patterns of human adaptation, one or another of which become increasingly prevalent with the passage of time.

During Period 5 in the Lithic Tradition, a new hunting technology, represented by narrow-necked projectile points used in bushy areas along streams develops, or is introduced, and is utilized as an alternative to the technology using large points in habitats of the open plain. In the same period, large domestic settlements dominate, but a new, much smaller size settlement appears for the

first time in low frequency. Subsequently, by 400 BP, the new, small-point hunting technology and restricted settlement size are the prevalent patterns. The same sequence of events marks the decline of pastoralism in the Metallic Tradition, wherein a more gradual replacement by hunting-oriented settlement and land use patterns is perceptible. Neither change is manifest in a replacement of one adaptation by a new, totally distinct one; rather, variability exists before the change and then the new variant becomes predominant with the passage of time. Therefore, natural selection can potentially account for these events, or more properly, the events meet the criteria of natural selection.

CHAPTER EIGHT

Time and Resource Niches

An organism's ecological niche consists of three primary dimensions: time, space and resources. In the preceding three chapters I have taken the first step toward defining the niches of the valley's human inhabitants by identifying the space dimension: the habitats exploited by human populations and people's patterns of adaptation to those habitats as reflected in distributions of tool and settlement types. Several times during the Holocene, changes have occurred in these patterns, and I am concentrating further efforts on three of these. Between Periods 5 and 6 (400 BP) hunting technology changes from a balanced use of open plain and canyon-stream habitats to one using the canyon-stream almost exclusively. At the same time, the sizes of domestic settlements which are here taken as indicative of the sizes of human groups, decline to one-third their former extent. Finally, during the Metallic Tradition, large permanent settlements and temporary settlements of moderate size, both associated with intensive pastoralism, give way to small, temporary settlements and a reduction in pastoral activity. This change is complete by the end of Period 8, around +2 BP. In reference to the model presented in Chapter 2 (Figure 1) I have answered the first question: changes have indeed occurred in the adaptive patterns of people living in the Pahsimeroi Valley.

To assess the role of climate in selecting for this change, two hypotheses are now posed: either (1) the observed cultural change coincides with and may be related to changes in resource utilization; or (2) the cultural change is not associated with resource use, but is the result of some social or demographic event that changes the space niche and adaptive pattern without altering any other aspects of the niche. If for any of the three cultural

changes mentioned above, Hypothesis 2 is the better answer, the change in adaptive patterns cannot be linked to climatic events or to change in any other aspect of the natural environment.

To test these hypotheses, I gathered data on the kinds and relative quantity of various biotic and abiotic resources and attempted to ascertain patterns of resource scheduling. For the Metallic Tradition, all information was obtained from the ground surface, since no buried occupations could be found. Biotic remains were collected along with other surface artifacts, the new floral specimens being found through a careful search of fire hearths and shallow dump areas. Abiotic resources were observable as the raw materials used for construction or tool and vessel manufacture or were inferred from feature forms through analogy with modern Metallic Tradition activities.

Stone and water were the only abiotic resources observable in surface sites of the Lithic Tradition.

Chemical decay and mechanical weathering had long since destroyed most traces of biotic resources on these much older sites, and only tiny bits of calcined bone and tooth enamel remained in a few occupations (D4Q, G2F). Consequently, biotic data were obtained by excavating sites in settings where rapid burial had enhanced the likelihood of bone and plant tissue preservation. Excavations also provided a check on the applicability of the Northeastern Valley's projectile point chronology to the upper Pahsimeroi area.

This chapter provides a detailed presentation of the techniques used to extract information on resource use and presents a summary of the results.

Metallic Tradition Resource Use

Abiotic Resources

Abiotic resources from which the artifacts of this tradition are made consist primarily of silica (glass), various metals, clay (ceramics) and the polymers used in plastics. Because there is no

evidence that any of these raw materials were extracted from the Project Area and no known sources exist there, it is reasonable to conclude that these materials were acquired elsewhere. The use of two other abiotic resources can be inferred from features: water, transported through irrigation ditches and soil, evidently used as a substrate for domestic plants or irrigated natural pasture.

Soil and water were manipulated only during Period 8, from 36 to 16 BP, so some change in the use of these resources is evident. However, only one field was watered by the entire complex of ditches and soil and water manipulation were not major aspects of the local adaptive pattern. Field and ditch abandonment is thus not in itself a significant change in the overall adaptation of people in the Project Area but when considered in conjunction with changes in the exploitation of biotic resources, it forms part of a general pattern of changing resource use.

Biotic Resources

Floral and/or faunal remains occurred as artifacts in nearly all Metallic Tradition occupations, in most instances consisting of wood used as building material or fuel. Unfortunately, wood was only collected when the bark surface was clearly visible, and then only for chronological purposes. Field observations identify most woods as either Douglas fir (Pseudotsuga menziesii) or cottonwood (Populus cf. tremuloides). Both were used for firewood and fence-posts, but only Douglas fir served as building material. In the absence of quantitative information on all wood observed in the occupations, no statement about changing utilization of tree species can be made.

Faunal remains and plant fragments other than wood were collected assiduously, but were less extensively distributed. Animal bones occurred in seven occupations, while flora were recovered from only three (Table 49). Periods 7, 8 and 10 are represented, but no biotic information was recovered for Period 9. Faunal identifications were made by comparison with specimens housed in the Museum of

Vertebrate Zoology at the University of California, Berkeley and the Thomas Burke Memorial Washington State Museum, Seattle.

All flora belonged to three common domestic taxa and were readily identified without the aid of comparative material. Quantities of faunal remains are presented as numbers of identified specimens (NISP), that value being preferable to the minimum number of individuals (MNI) for reasons discussed in Chapter 9 (cf. Grayson, 1979a, n.d. and elsewhere). Plants are listed as NISP also, except where large, uncounted masses of seeds occurred.

Table 49. Remains of Biotic Resources Recovered from Metallic Tradition Occupations of Periods 7, 8 and 10*

Occupation	Period	Fauna							Flora				
		Antilocapra	Odocoileus	Ovis sp.	Ovis aries	Bos	Sylvilagus	Galliform Birds	Total Fauna	Zea mays	Prunus	Avena	Total Flora
C5J	10	1	3					3	7		+	+	
F1C	10	9				3	1	1	14	2		2	
F1P1	10	4				1		3	8	2		2	
D6A	10	2							2				
F1Pe/F2B1	8	8	1	1	4	17		2	33		4	+	4+
E1H	7				1				1				
E3A	7					1			1				
Totals		24	4	1	5	22	1	9	66	4	4	+	8+

*The plus sign designates the presence of large, uncounted masses of seeds.

Floral remains were extremely scarce, numbering only eight individual specimens and two large masses of seeds. They include corncobs (Zea mays), peach pits (Prunus sp.) and oats (Avena sp.). In addition, it is highly unlikely that any of these plants were grown in the Project Area, with the possible exception of oats. Corn occurred only in essentially modern occupations of Period 10 (+20 to +25 BP), and the climate of the Upper Pahsimeroi Valley is now unsuitable for the growth of this species. Likewise, although climatic conditions may have differed from the present during Period 8, it is highly unlikely, in view of modern climatic records that conditions were sufficiently different to allow the growth and reproduction of peach trees. In the Northeastern Valleys region, killing frosts occur during May in the towns of Salmon and Challis, over 1000 m below the Project Area, precluding the production of most fruits (U.S. Weather Service). To make the Project Area suitable for this species would take a climatic change greater in magnitude than any known to have occurred anywhere during the Holocene. Peaches and corn have certainly been imported from outside the Project Area. Oats might have been raised locally, and no argument can be made for a significant change in its utilization.

The reverse is true for certain species of animals. Six faunal taxa are distinguishable, including pronghorn (Antilocapra americana), deer (Odocoileus cf. hemionus), domestic sheep (Ovis aries), cattle (Bos taurus), cottontail rabbit (Sylvilagus sp.) and various kinds of galliform birds (e.g., grouse, chicken). Numbers of faunal specimens found in each occupation are ordinarily small, so assemblages have been combined by time period to permit comparison (Figure 31). Periods 7 and 8 are contrasted with Period 10 to show whether changes in the exploitation of fauna coincide with the shift in adaptive patterns described in Chapter 7.

Marked changes do occur in the presence and proportional representation of four taxa: pronghorn, sheep, cow and the galliform birds. Because birds could not be identified with any certainty due to the absence of landmarks, only the changes in artiodactyl taxa can

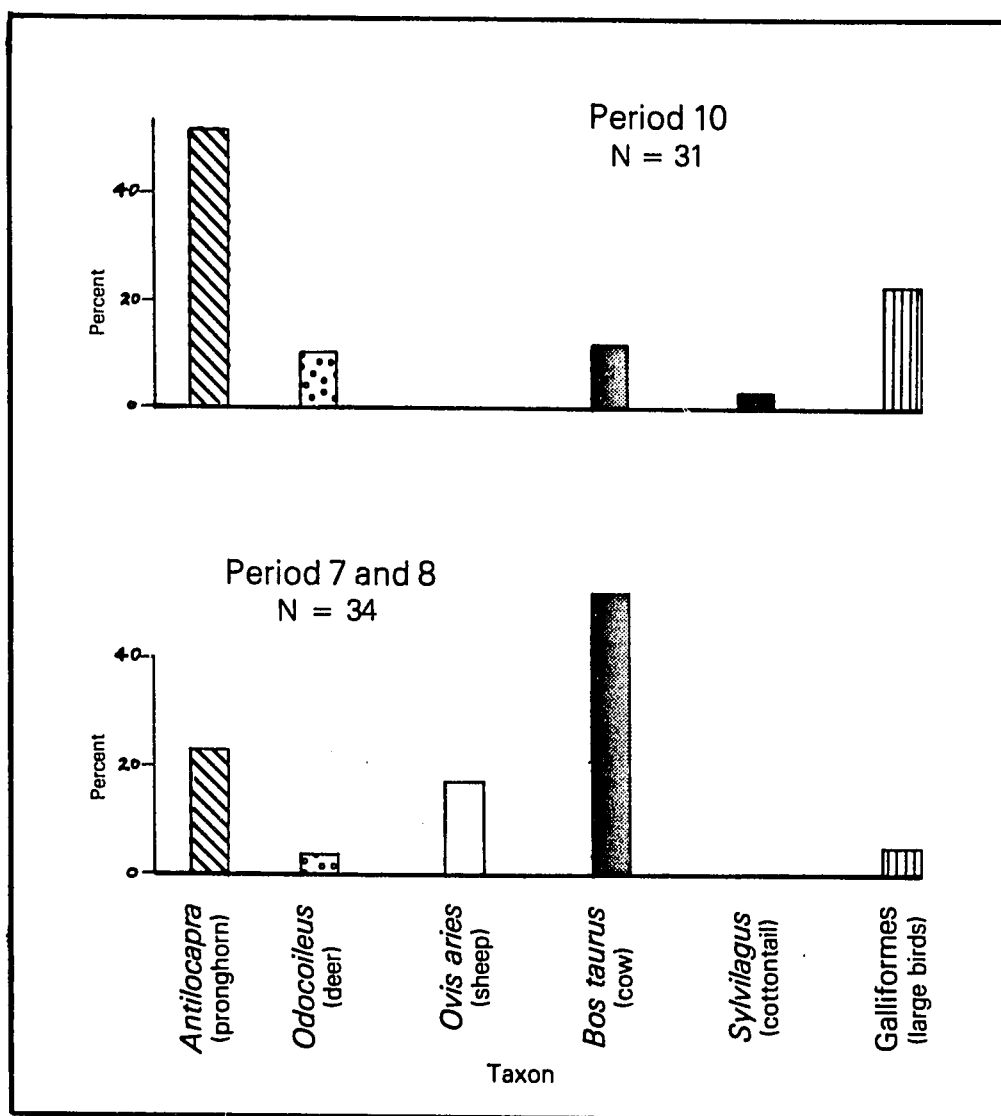


Figure 31. Utilization of faunal taxa: a comparison of Periods 7 and 8 with Period 10.

be considered. As Figure 31 shows, cattle decline sharply, pronghorn increase and domestic sheep disappear between early and late periods. Deer also show a slight increase. When these changes are taken together, they mark a shift from domestic taxa, Bos and Ovis, to wild taxa, Antilocapra and Odocoileus. Periods 7 and 8 differ with Period 10 on the basis of wild versus domestic taxa produced significantly ($\chi^2 = 15.933$, $p < .001$). There is, therefore, a significant change in the faunal resources utilized by the area's Metallic Tradition inhabitants; domestics predominate in earlier periods; wild species, mainly pronghorn, in later periods.

There is also some indication of a change in the domestic species used for food. One domestic species, the horse (Equus caballus) was present (as horse shoes and isolated faunal remains attest), but not used in such a way that their bones were deposited in occupations. Remains of cattle are present in both early and late contexts, but sheep bones and horseshoes are only found in Periods 7 and 8. The difference in domestic food animals, cow and sheep can be attributed to sampling error ($p = 0.417$), but data on isolated faunal remains (Table 45) exhibit the same pattern. In addition, the horse is the most common species among isolated fauna in Periods 7 and 8, but is absent later on.

Even though this change from the horse-cow-sheep complex to the cow alone is represented by a small sample, there is a low probability that the difference between early and late periods is due to chance. A Fischer Exact Test on cow versus sheep-plus-horse for early and late collections of isolated faunal remains gave a probability of under 0.027. When faunal remains from occupations are figured into the calculations, p is still less than 0.047.

Remains of biotic resources are curiously absent from Period 9 assemblages. What makes this fact seem odd is that bones and plant fragments were commonly found in both older and younger occupations, so that time itself is not a factor. There are two possible explanations: (1) no faunal or floral remains were deposited in Period 9 occupations because of a difference in function from earlier and later occupations or (2) because of differential

preservation between environments in which the occupations occurred. The first hypothesis is less likely. Occupations of Period 10 which contained faunal remains are all of Settlement Type MS2, as are most occupations (80%) belonging to Period 9 (Figure 30). The difference is probably not functional.

Figure 30 (Chapter 7) supports the second hypothesis. Period 9 occupations all occur in open settings away from the brushy riparian zone, whereas all Period 10 occupations are found in the latter environment. The environmental settings are different. Old bones (weathering classes 2 and 3) are common in environments where Period 9 occupations occur, so differential weathering probably is not an important factor. One possible cause for the difference is exposure to winds, which would carry scent of fresh bones greater distances in the open environment, enabling scavengers to find them, and would blow ashes from fire hearths in one setting but not the other. The difference may therefore be that Period 10 occupations are more protected than their earlier counterparts.

Because Periods 9 and 10 have similar land use patterns and occupations are functionally similar, I shall assume that the kinds of resources being utilized during this period are much like those of Period 10.

Scheduling

There is no unequivocal information available on resource use scheduling during the Metallic Tradition. All artiodactyl remains were either from fully mature individuals or were so fragmentary that accurate aging was impossible. Large birds provided one potential source of seasonal data, but because none could be identified to species, they are also useless. Floral remains were the strongest possibility for seasonal data. All are seeds or seed heads, and all three commonly ripen in summer or early fall. However, since oats is eminently storable under dry conditions (as its presence in perfect condition after 25 years can attest) and both corn and peaches had to have been imported from outside the

Project Area, none of these plants presents incontrovertible evidence of human occupancy during the summer and fall months.

Summary: Changing Resources of
the Metallic Tradition

There is a change in the resource niche of Metallic Tradition peoples that occurs by the end of Period 8 and coincides with and is closely related to changes in adaptive patterns. There is abundant evidence that during Periods 7 and 8, pastoralism was the dominant aspect of human adaptation to the Project Area. Permanent building-corral complexes are present and the remains of domestic animals are scattered over the landscape in much greater abundance than during later periods. Other land use activities are relatively unimportant. Biotic resources used during this time were predominantly domestic plants and animals, with only the latter obtained from the Project Area. Horses, cattle and domestic sheep were all being raised, but only cattle and sheep were used as food. Wild game, mostly pronghorn, provided a secondary food resource. At least one field was being irrigated either to raise a crop or improve native forage (probably the latter - see Chapter 6: Sagebrush dating).

By Period 10, and presumably Period 9 as well, pastoralism is no longer of primary importance. Large, permanent settlements have been abandoned and replaced by tiny, temporary camps, isolated remains of domestic animals have declined in number, and the one irrigated field has returned to its native state. At the same time, isolated finds indicate an increase in activities associated with hunting (cartridges) along streams and in the open plain. Remains of biotic resources confirm the reduction in pastoralism's importance. Wild ungulates, especially pronghorn are more abundant than domesticates in Period 10 assemblages. In fact, the ratio of wild to domesticates ungulates has been almost exactly reversed. There is also a change in the kind of domesticates used from cattle, horses and sheep in Period 8 to cattle alone in Period 10. Sample

sizes are very small, however, and these results must be used with caution.

Given available data, Hypothesis 1 is the better alternative in this case, and we will proceed in subsequent chapters to determine whether environmental change selected for the new form of human adaptation.

Lithic Tradition Resource Utilization

Abiotic Resources

Only two classes of abiotic resources were used extensively by Lithic Tradition peoples: stone and water, and there is not evidence that patterns of use of either resource changed significantly over 8000 years. All dated types of settlements occur within 200 m of water; all domestic settlements are within 50 m.

Lithic material utilization is a complex matter because over 25 types of material are represented. Table 50 lists the rank order of numerical abundance for the ten most common materials used in each occupation. No temporal tendencies are readily discernible from these data except that older assemblages tend to be slightly more diverse. However, sample sizes are also larger for older occupations, and this fact alone may account for the diversity. This fact, coupled with the lack of any association between dated settlements and lithic material quarries supports the conclusion that there is not likely to be any relationship between lithic resources and changing adaptive patterns.

Biotic Resources: Excavations

The primary purpose of excavation was to recover floral and faunal remains from occupation sites belonging to as many of the Lithic Tradition Periods defined in Chapter 7 as possible. A secondary, but equally important purpose was to provide an independently dated sequence of occupations to assess the applicability of the Northeastern Valleys chronology to the Project Area. To meet

Table 50. the Temporal Distribution of Lithic Raw Materials
Among Domestic Settlements

Period	Occupation	Lithic Material, by Rank									
		1	2	3	4	5	6	7	8	9	10
6	D4J	M	J	X	W	D	B	O	X	I	
	D9E	X	Q	O	J	M	W	I	S		
	G2G	I	S	O	W	M	J	X	X	X	
	G2F	S	I	O	C	X	W	J	X		
5	A7X	M	O	Q	B	I	C	S	X		
	D7X	W	M	Q	O	J	I				
	D4Q	W	D	I	O	J	M	S	C	B	X
	D4Z	D	J	W	S	X	M	I	O	X	
4	A1B	M	Q	B	W	J	X	D	O	X	I
	A1Y	Q	O	M	B	J	X	I	X		
	A1Q	J	W	I	B	Q	M	O	X	X	X
2	D4S	J	W	O	I	B	M	D	C	X	Q
	D4R	W	J	D	I	X	X	Q	X	O	X
1	A1U	J	O	M	S	I	Q				
	A1C	O	Q	I	X	J	B	S	M	X	X
	A1V	J	B	M	I	S	X	O	X	C	

W. White Chalcedony from Burnt Creek
O. Obsidian, nonlocal
I. Ignimbrite, nonlocal
M. Multicolor Chalcedony, local
C. Chert from Antelope Valley area

D. Rhyolite from Donkey hills
S. Chert from Springhill/Double-
spring
J. Red Jaspers from various local
sources
B. Brown/ Green Jaspers, local
Q. Quartzites, all locally avail.
X. Other, Source Unknown.

these goals, sites for excavation were chosen on the basis of three criteria: (1) potential for containing the remains of biotic resources, (2) potential for geologic stratification, and (3) apparent site integrity.

Only four archaeological sites were found which clearly contained resource remains. Of these, 10CR334 and 10CR526 are on the floodplains of perennial streams and the others, 10CR29 and 10CR527 are at springs. The stream-side sites are both geologically stratified and neither appeared to have been as badly disturbed by rodent activity as those near springs. Spring sites had also been extensively modified for irrigation and livestock watering and one (10CR29), had been ravaged by amateur artifact collectors. (More recently, Druss [1981] has conducted small scale excavations at 45CR29, but has found little in the way of floral and faunal remains in undisturbed portions of the site area.)

Because 10CR334 and 10CR526 achieved higher rankings in each of the three criteria, only these two sites were excavated (Figure 32). A fifth site, Buck Creek Cave (10CR525) was later found and appeared to have great potential for a well stratified record of both lithic artifacts and resource remains. As it turned out, the cave had rarely been visited by people, but did contain a long sequence of non-cultural faunal remains (see Chapter 9). Two projectile points were found there, however, and because of their utility for chronology confirmation, these are included with the chronology discussions of the present chapter.

Sampling. The choice of excavation units was based on a stratified, systematic, unaligned sampling scheme (Haggett, 1965). The parameters of each buried occupation could not be accurately estimated without extensive test excavation or coring (cf. Brown, 1975; Chatters, 1981b) and such an effort was not feasible in the framework of the present study. Consequently, sites were divided on the basis of surface topography or soil conditions into areas where resource remains could be expected or were known to occur

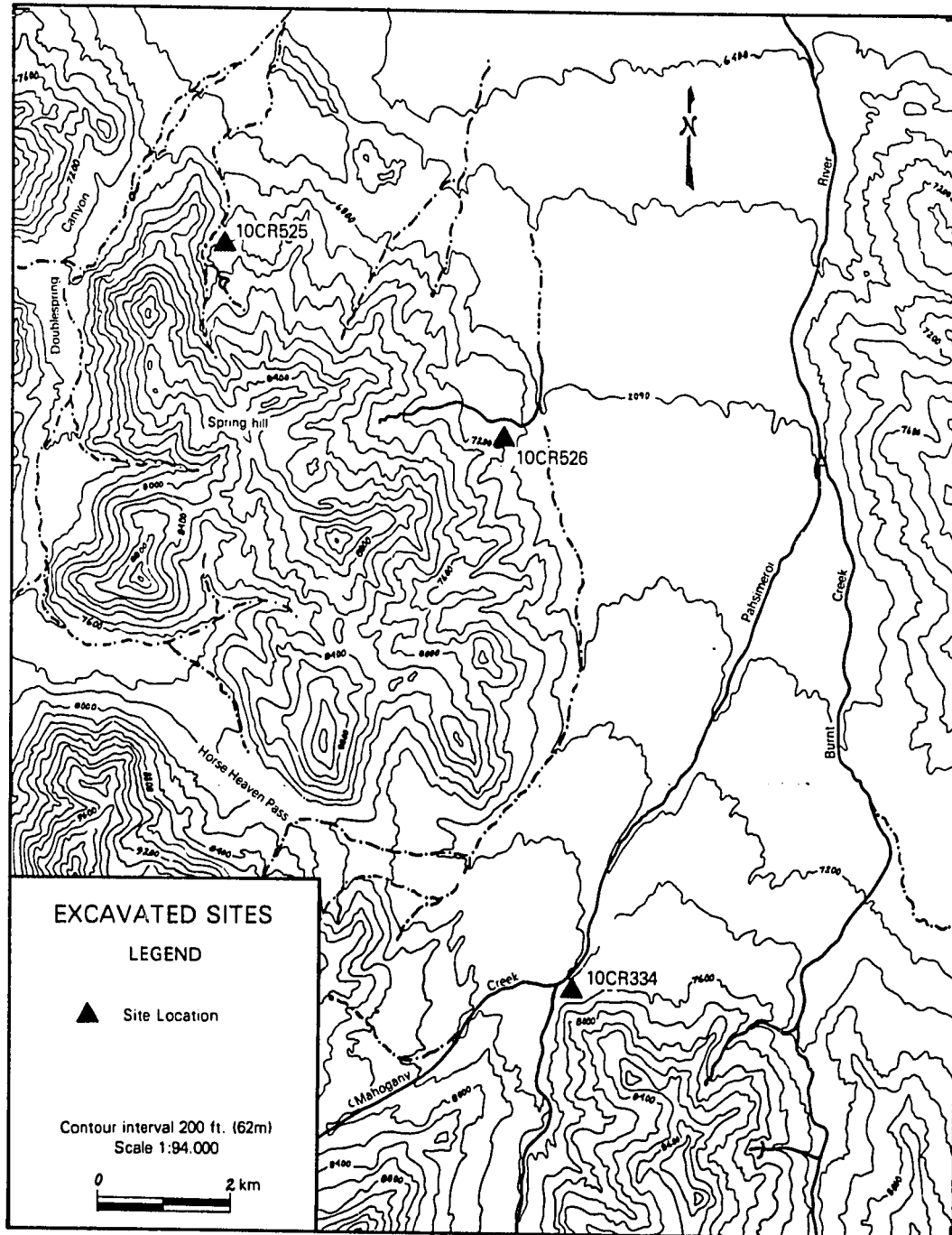


Figure 32. Map of the Project Area, showing Lithic Tradition sites excavated to obtain biotic resource data.

versus areas about which nothing was known. This procedure was used to ensure recovery of some resource remains, while reducing the chances of entirely missing activity areas within a site.

Because of parameter estimation problems, it was difficult to choose a sampling fraction which would provide an equal amount of data from each occupation at a site. This problem was handled, though certainly not solved, by placing a grid over the site area which exceeded the average size of habitation units found elsewhere on the surface. At several surface occupations, most notably A1Q (10CR256), single occupations clearly consisted of repetitious habitation units, including a dwelling plus the activity areas associated therewith. The average size of these units (10 m square) was transposed on each site area to be excavated and treated as the sampling population. This grid was then divided into sampling strata and a 30 to 40 percent sample of each stratum chosen for excavation.

Excavation was not based on statistical sampling at either 10CR526 Area R or at Buck Creek Cave. Site area 10CR526R had been surface collected during the survey phase of investigation (Occupation G2G). The locus of faunal remains had thereby been identified and could be entirely excavated. Sampling of Buck Creek Cave was based on cave structure, as discussed in Chapter 9.

Technique. In the absence of a priori knowledge about geological stratification, vertical units were in all cases arbitrary, with depth measurements taken from the surface of each horizontal unit. Arbitrary levels were 20 cm at 10CR334 where the geologic deposit was over 1 m deep, and 3 cm at 10CR256, where floodplain silts were shallower. Horizontal excavation units were one square meter, usually clustered as 2m x 2m quadrants. Precise three dimensional locations were not recorded for each artifact; finds were collected by excavation unit for each arbitrary level.

All site matrix was thoroughly screened. Initially eighth-inch mesh was used exclusively, so that small faunal remains might

be recovered, but this time consuming procedure was replaced before excavation began at either site. Eighth-inch mesh was then used to screen only one unit in four to provide a sample of microfaunal materials, while all other units were sifted through quarter-inch mesh.

Sites. Site 10CR334 is an extensive site where artifacts are scattered over the entire surface of the lowest alluvial terrace of the Pahsimeroi River, opposite the mouth of Mahogany Creek (Figure 33). The site lies within Tract A in Stratum I.

Bone and artifacts had been seen weathering out of the river bank 50 m downstream from the mouth of Mahogany Creek. A grid of 10m x 10m was set up at this location and was stratified by separating those squares within 3 m of the bank, where bone had been seen (Stratum Q), from those units a greater distance from the cut bank which might lay outside the concentration (Stratum R).

A 30 percent sample of each stratum was chosen for excavation. Squares in Stratum Q were excavated first so some faunal remains would be recovered if time did not permit complete coverage of the gridded area. In fact, only 10 of 100 units were excavated; eight in Stratum Q, 30 percent of that area, and 2 units, only 3 percent, in Stratum R. Because the site was deep and stratified, and since the high clay content made screening difficult, no further work could be done at the site in the time allotted to its study.

The site matrix consisted of a series of alluvial deposits, including sands and gravels overlain by a sequence of six episodes of active silt deposition (Figure 34).

Weak soils with prismatic structures had developed on the lowest silt deposit (Soil V), and on the upper four silts (Soils III, II and I and the surface soil), while a crumb structure characterized Soil IV (Figure 34). Cultural materials, including faunal remains and simple features (charcoal stains and fire-cracked rock concentrations), were found on each of the upper four soils. Only a few faunal remains were present in Soil V.

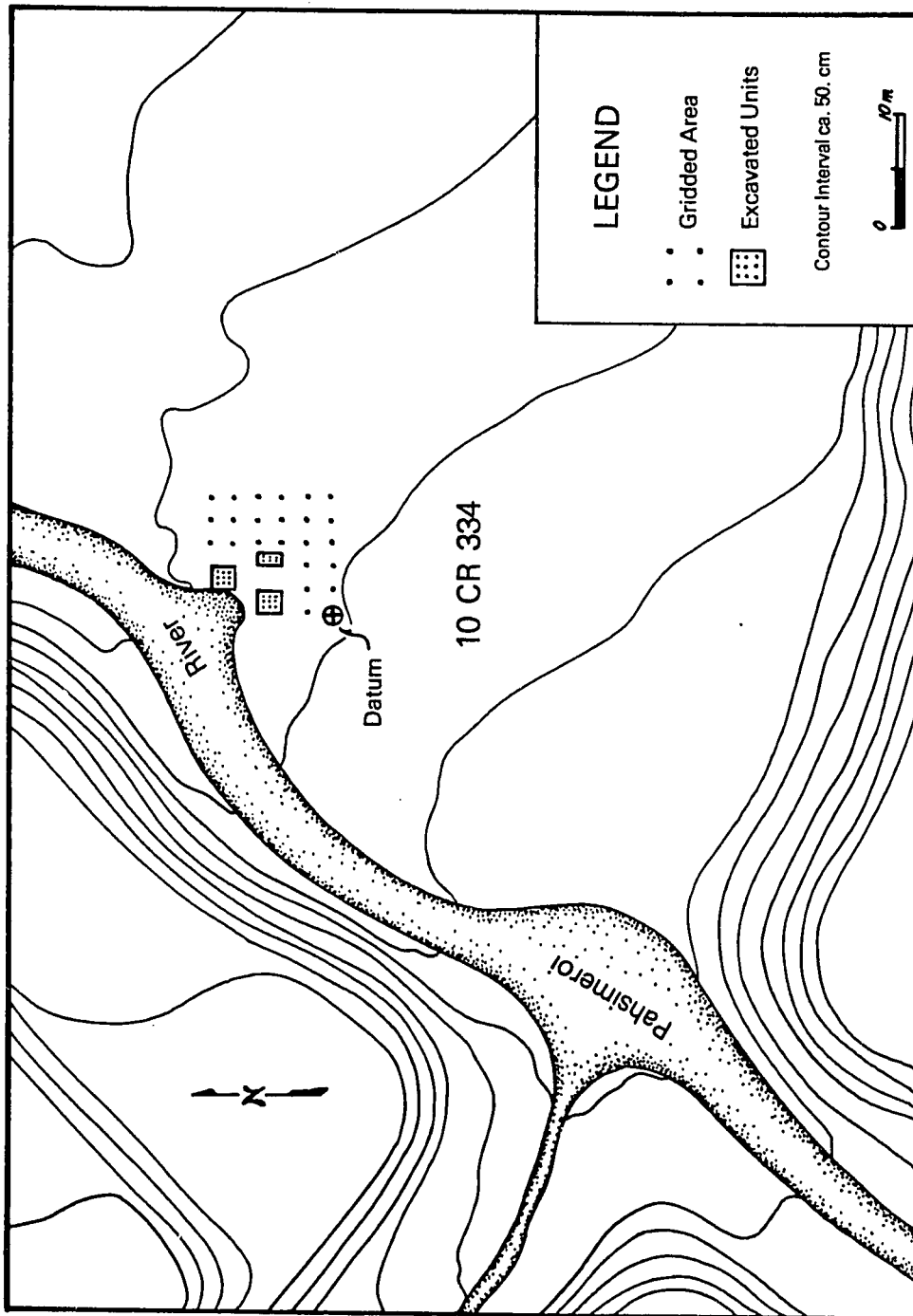


Figure 33. Topographic map of Site 10CR334, showing the location of excavation units.

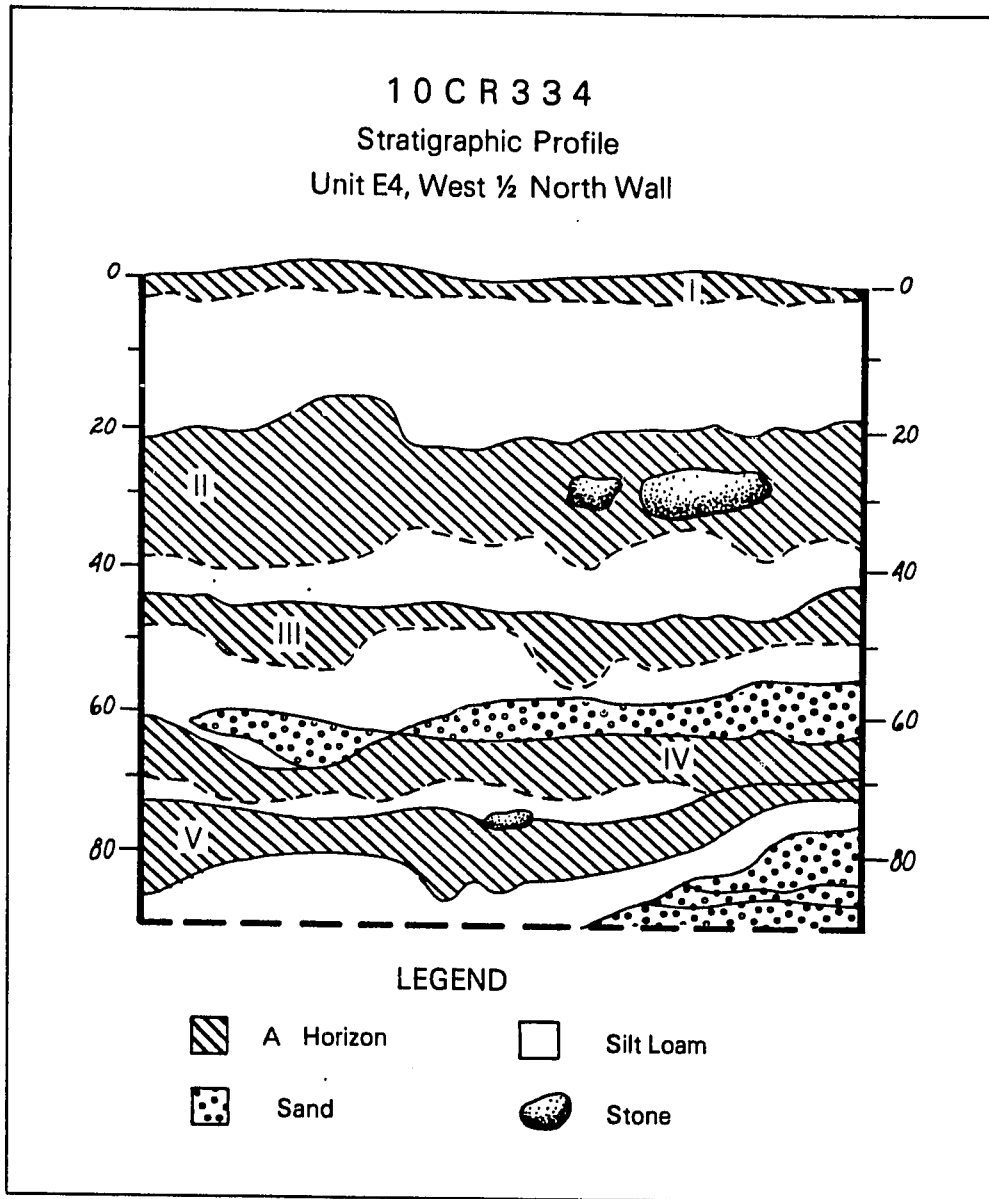


Figure 34. An example profile from Site 10CR334. Note the five A horizons. Soils I through V weathered into layers of silt loam.

Site 10CR526 is located on the toe of the Spring Hill landslide and is included in Transect G2. Two areas of this site were excavated; Area T, which lies at the edge of the small stream, and Area R, which is in a swale 25 meters south of the creek and corresponds to occupation G2G (Figure 35).

Area T is level and approximately 10 m in diameter. Some depth of sediment appeared to have accumulated here and recent erosion had not been extensive. An 8m x 10m grid was placed over this surface and divided into two areas: (2) dense grass cover near water level, and (2) sparse grass cover at a 20 cm higher elevation. This stratification procedure was used to ensure that if differential preservation of floral and faunal remains existed in the two areas, this bias would have been accounted for. A 40 percent sample of each stratum was chosen for excavation. Stratum 1 proved to be extensively disturbed by cattle and to have poor bone preservation, so only 20 percent of this area (4 square meters) was investigated. The entire 40 percent sample of Stratum 2 was obtained.

During excavation of the first sample units, it became apparent that there was some cultural stratification of the deposit, although the original landslide surface lay at a depth of only 10 to 15 centimeters and geological stratification was not readily discernible. Therefore, the site was excavated in 3 cm levels.

The site was stratigraphically simple (Figure 36). Alluvial silts (Unit I) overlay the original landslide deposit (Unit II). The uppermost 2-4 cm of Unit I is an Ao soil horizon comprised of litter, rootlets and a small fraction of silt. Below this, to between 8 and 14 cm is a gray-brown silty clay loam with a strong crumb structure and a few angular stones. This layer was probably deposited by the small stream that flows past the site (Figure 35). Unit II is a yellow brown sandy clay with angular stones, the uppermost few centimeters of which has undergone some soil development and has a light gray-brown color, finer texture and crumb structure.

Arbitrary level 0-3 encompassed the Ao horizon of Unit I; 4-6, 7-9 and occasionally, deeper levels were excavated in Unit II.

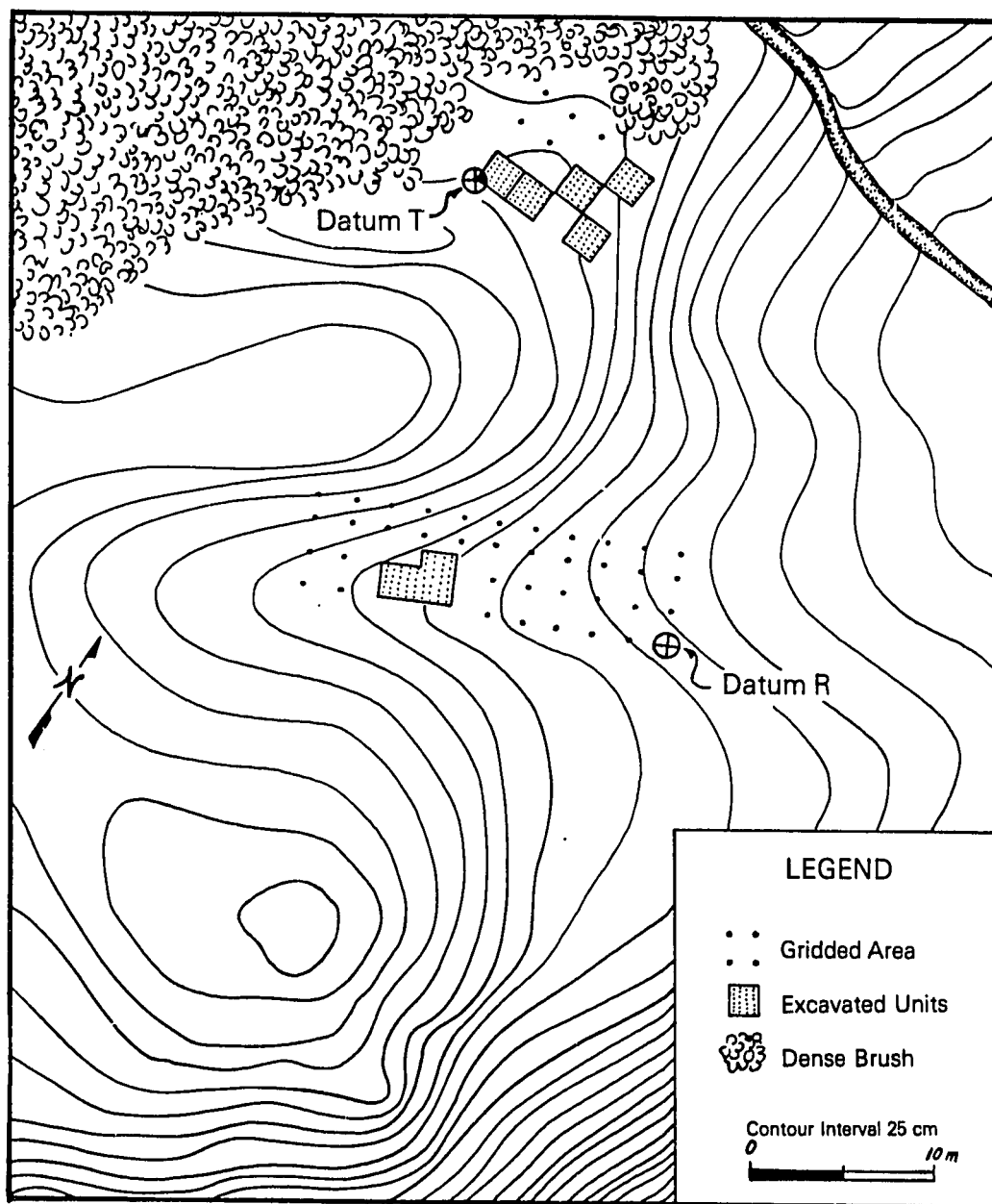


Figure 35. Topographic map of Site 10CR526, showing the location of excavation units in areas R and T.

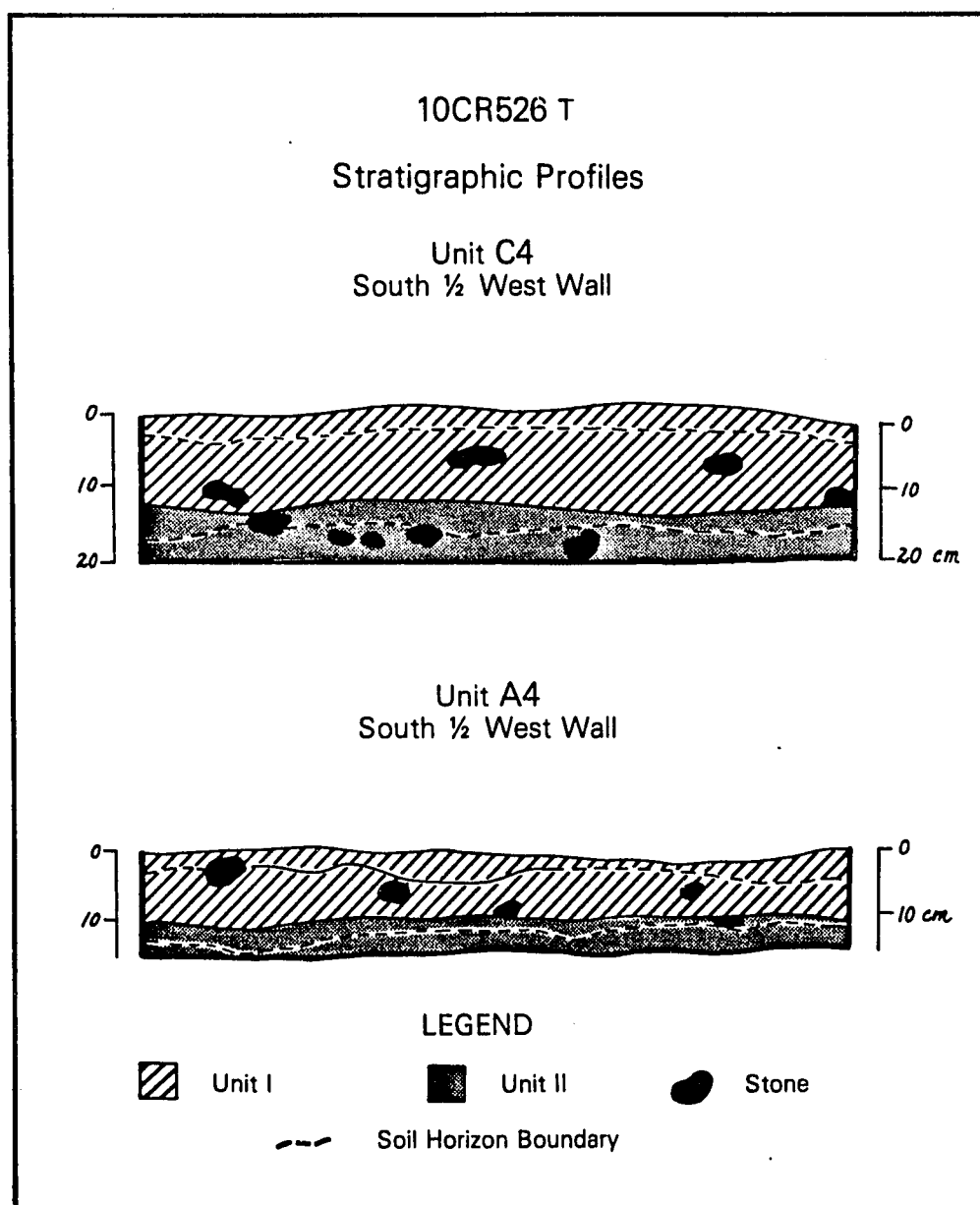


Figure 36. Profiles from 10CR526T, showing alluvial silt (Unit I) overlying landslide deposits (Unit II). All artifacts were found in Unit I, most between 3 and 9 cm below surface.

One feature was found associated with the occupation in level 4-6 consisting of a 15 cm deep basin, 50 cm in diameter filled with charcoal and covered by angular, fist-size rocks and soil.

10CR526 Area R is located 25 meters south of Area T in a slight swale (Figure 35). Numerous artifacts, including lithics, ceramic sherds, and fragments of calcined bone had been recovered from the surface during survey of transect G2 and the sources of ceramics and bone were located from a map of artifact distributions (Chatters, 1977, Figure 7). Six contiguous 1m x 1m units were excavated to a depth of 5 cm over the area of maximum concentration of these artifacts. A fragmentary pot and a bone-filled fire hearth were located, along with hundreds of flakes, a large, heavily-worn basalt artifact and fragments of two large bifaces. The pot lay crushed less than 1 m from the hearth area (Chatters, 1977, Figure 7), and had apparently been short and cylindrical, with a diameter of about 15 cm. It has a dark brown fabric with coarse sand temper and plain surface treatment. Evidently made by modeling, this pot is the type of ceramic known as Shoshone ware (cf. Coale, 1963).

The hearth was a basin 5 cm deep and 80 cm in diameter. Flecks of charcoal and over 300 fragments of bone came from within, but there was no fire broken rock. All bone was artiodactyl and included fragments of mandibles, teeth and long bones.

Dating: Checking the Northeastern Valleys Chronology

Seven occupations are represented in the two excavated sites; Soils I and IV at 10CR334, Levels 3-6 and 7-9 (and below) at 10CR526T, and the single occupation of 10CR526R. Complete projectile points or identifiable fragments were found in each occupation (Table 51) and Carbon 14 dates were obtained on samples from hearth features in four of the occupations (Table 52). In addition, Soil IV can be assigned a maximum age on the basis of a date on alluvial charcoal from Soil V. Projectile points and radiocarbon dates both make it possible to determine occupation ages and provide

a means for checking the Northeastern Valleys projectile point chronology (Chapter 6).

Dates obtained by the index fossil approach and based on the point chronology are compared against absolute dates in Table 52, which also includes the additional chronological data provided by two projectile points found in the 20 - 30 cm level of Buck Creek Cave. Absolute dates on the Buck Creek specimens are mathematically interpolated between dendrochronological and radiocarbon age determinations (Chapter 9, Figure 41, Table 57).

Table 51. Projectile Points from Excavated Occupations, listed by Historical Type

Site	Stratum	Projectile Point Type									Total
		C1/2	C3	C4	C4/6	C6	S2	S3	S4	U1	
10CR334	Soil 1	1					2	2			5
	Soil 2								1		1
	Soil 3	2		1							3
	Soil 4			1							1
10CR526R	0 - 5						2				2
10CR526T	4 - 6	1			2	1	2		2	1	9
	7 - 9		2			7					9
10CR525	20 - 30							2			2

The dates are consistent. In all cases but one, the radiocarbon age falls within the age range assigned to an occupation by the index fossil approach. The exception is Soil 2 at 10CR334, where the index fossil date (400 - 700 BP) and radiometric date (1720 ± 70 BP) diverge significantly. The single classifiable projectile point from this component was a small, side-notched specimen of Type S4, which dates elsewhere in the Northeastern Valleys to

Table 52. Chronology of Buried Occupations from 10CR334 and 10CR526 and Buck Creek Cave (10CR525)¹

Site	Stratum	Predicted Age*	C14 age	Corrected Age	Consistent Date?
CR526R	1	100-400	225±95	300±95	yes
CR334	Soil 1	100-400	---	---	---
CR525	20-30cm	100-400	---	125-260 ^b	yes
CR526T	level 4-6	400-1300	425±85	505±85	yes
CR334	Soil 2	400-700	1720±70	1695±70	no
CR334	Soil 3	400-1800	1435±80	1400±80	yes
CR526T	level 7-9	1300-2500	---	---	---
CR334	Soil 4	1800-2500	1985±100 [‡]	1950±100	yes

¹comparing ages predicted from the projectile point chronology with radiocarbon dates. Occupations are placed in order from youngest (top) to oldest. Carbon dates are based on the Pennsylvania half-life of 5770 years.

*based on the Northeastern Valleys projectile point chronology (Chapter 6).

‡maximum age, based on date from the surface of Soil V.

‡from Ralph and Michael (1974).

^binterpolated date based on sediment compression model (Chapter 9).

after 700 BP, 1000 years later than this Carbon 14 date would suggest. Two possible conclusions can account for the discrepancy. Either (1) the type was in use for a much longer time in the Pahsimeroi Valley than in the Birch Creek area, (2) the radiocarbon date is inaccurate or (3) it dates a different event than the points' deposition. When other radiocarbon dates are taken into consideration, the second conclusion is clearly the correct one. Soils 3 and 4 have dates of 1435 ± 80 years and over 1985 ± 100 years, respectively, and both dates are consistent with associated projectile points types. The stratigraphically higher, and therefore later Soil 2 dates 1720 ± 70 , a finding which is both typologically inconsistent and stratigraphically out of sequence. Therefore, the index fossil date of 400 - 700 BP is the closer age approximation for Soil 2. Because 1720 year date came from a concentration of organic carbon in an alluvial deposit, the carbon was reworked; hence, the anomalous date.

Data in Table 52 give ample reason to believe that the Northeastern Valleys chronology is applicable to the Project Area. The seven occupations can be assigned to time periods as follows: Period 4: 10CR334, Soil 4 and 10CR526T, 7-9 cm; Period 5: 10CR334, Soils 3 and 2 and 10CR526, 3-6 cm; Period 6: 10CR334, Soil 1 and 10CR526R.

Comparability of Buried Occupations

To make valid observations about temporal variation in the human resource niche, I must be certain that all occupations represent approximately the same kind of settlement. If observations about temporal variation in the biotic resource niche are to have any meaning, it is necessary that all seven buried occupations represent comparable kinds of settlement. This is not to say that they must all belong to the same Settlement Type, as defined in Chapter 5, for this would preclude discovery of functional change. Rather, all should be either domestic settlements or small, specialized activity loci, for example, but not a mixture of the

two. If the kinds of settlement were mixed, differences might occur among biotic resources because of differences between occupations in number of activities performed, not because of an actual change in the ecological niche of the site's human occupants.

Comparability is ascertained using the functional analysis described in Chapter 5. If tool type inventories of the seven occupations do not differ significantly from each other, they all represent approximately the same kind of settlement and their biotic resource data are comparable. Any occupation that is significantly different from the others cannot be used in the present analysis.

To be sure, the measure of significance used in this instance cannot be an interval scale statistic: the occupations are not expected to be identical to each other. Several factors mitigate against close similarity among tool assemblages, including: (1) variations in lithic material, (2) differences in the speed of burial, (3) functional change, and (4) sampling error. First there are extreme differences among occupations in the lithic materials used for tools, which as I mentioned in Chapter 5, may cause variations in tool type frequencies even though the activities that produced the tools may have been the same. Most stone at 10CR334, where various proportions of obsidian, ignimbrite, chalcedony, quartzite and chert occur in each occupation. The blue-gray cherts will wear more quickly than the chalcedonies, cherts and quartzites and hence tools will show different patterns of wear from the same use.

Speed of burial is important because a sharp edged flake covered by alluvium soon after discarded is protected from the many forces of mechanical weathering that impinge on surface artifacts (cf. Knudson, 1979; discussions in Hayden, 1979). Quickly buried tools are also available for reuse for a shorter period of time than are objects that remain exposed for centuries. This bias cannot be eliminated, since the length of time between deposition and burial of an occupation is usually unknown and unknowable.

Third, if resource use has changed, some degree of change in the proportionate performance of activities might occur, and hence, proportionate frequencies among tool types are also likely to change. To expect functional identity is to deny change. Finally, there is the problem of sampling error. The areas excavated from each site and the number of tools in each class are usually small, especially when compared with results from surface collections of entire occupations. Differences in tool inventories due to sampling error may be as great as the actual functional differences between the complete occupations, so long as the occupations come from the same kind of settlement.

Because of these intervening variables, I chose an ordinal scale rank correlation coefficient, the computationally simple Spearman's Rank statistic r_s to compare assemblages. Tool type frequencies are presented in Table 53. To apply the statistic effectively, it was necessary to reduce the number of 0 value ties in rank by combining types in the same manner as for small occupations discussed in Chapter 5 (grouping Types 1, 7; 3, 5; 4, 6, 11) and adding together the rare values of Types 8 through 10. Seven variables remain for comparison.

The matrix of similarity coefficients (Table 54) shows that all occupations are similar beyond the .05 level of probability with 9 of 21 values significant beyond the .01 level. Given the constraints of this data set, there is no significant functional difference between occupations; all represent the same or similar type of settlement. Because one occupation in 10CR526R (G2G) has already been identified as a domestic settlement, an assignment of all occupations to this category is also appropriate. The presence of hearth features in most occupations (the exception being 10CR526T, 7-9) supports this conclusion.

Table 53. Tool Type Frequencies for Lithics Excavated from 10CR334 and 10CR526T and R

Site/Stratum	Tool Types													T
	1	2	3	4	5	6	7	8	9	10	11	12	13	
CR334/Soil 1	9	3	8	5			2			1	1	1	6	36
Soil 2	5		2	1		1	1		1		2	1	2	16
Soil 3	10		3	2		1			1		1	2	3	23
Soil 4	11	1	7	6	2		2	1			4	1	3	38
CR526T 1	8		6	7				2					13	36
2	22	1	6	4	2	3		5	1			4	15	63
CR526R 1	8	0	4	2	0	0	1						2	18

Biotic Resources: Results

Flora. Despite efforts to recover floral remains from hearth features by flotation, nothing but wood charcoal, mostly from sagebrush (*Artemisia* spp.) and various members of the Salicaceae (willow, cottonwood) could be found. Both taxa occurred in nearly every feature and, because both have probably remained continuously available along stream banks, no further analyses were performed on these data.

Fauna. Faunal remains were abundant in all occupations. Between 300 and 400 individual bone fragments were collected from each, and varying proportions of these were identifiable to genus or species (where genera are locally monotypic, to species). Identifications were made by comparison with the extensive skeletal collections at the Museum of Vertebrate Zoology, University of California, Berkeley.

Ungulates dominate nearly every assemblage (Table 55) with lower frequencies of cottontail (Sylvilagus), marmot (Marmota), porcupine (Erethizon) and occasional occurrences of sage grouse (Centrocercus) and small rodents. In 10CR334 a common, and occasionally the most common taxon, is ground squirrel (Spermophilus). However, the presence of this taxon is probably not due to human activity.

Table 54. Matrix of Spearman's Rank Correlation Coefficients r_2 , Comparing Excavated Lithic Assemblages on the Basis of Tool Type Frequencies*

		10CR334				10CR526T		10CR526R
		Soil 1	Soil 2	Soil 3	Soil 4	1	2	
10CR334	Soil 1	1.00						
	Soil 2	.858	1.00					
	Soil 3	.875	<u>.982</u>	1.00				
	Soil 4	<u>.911</u>	<u>.911</u>	<u>.893</u>	1.00			
10CR526T	1	.804	.839	.822	.750	1.00		
	2	.858	<u>.893</u>	.875	.839	<u>.911</u>	1.00	
10CR526R		<u>.964</u>	<u>.893</u>	.875	<u>.947</u>	.804	.858	1.00

*p .01 for underlined values, p .05 for all others.

An artifact is anything with properties that cannot be attributed to natural processes (Chapter 2) and this concept is the basis on which cultural and natural components of an archaeofauna must be distinguished (Chatters, 1976b; cf. Irwin and Moody, 1978). For a

Table 55. Faunal Remains from Excavated Occupations*

Soil Site/Stratum	<u>Ovis</u> (bighorn)	<u>Bison</u> (bison)	<u>Antilocapra</u> (pronghorn)	<u>Marmota</u> (marmot)	<u>Spermophilus</u> (ground squirrel)	<u>Sylvilagus</u> (cottontail)	<u>Erethizon</u> (porcupine)	<u>Castor</u> (beaver)	<u>Lagurus</u> (sage vole)	<u>Thomomys</u> (pocket gopher)	<u>Centrocercus</u> (sage grouse)	<u>Passerine</u> (songbird)	Total
CR334/Soil 1	24	19	7		1	2	3	1					57
Soil 2	18	0	20		10		3				1		52
Soil 3	23	2	15		15				1			1	57
Soil 4	9	2	2	1	20	4	2			1			41
Soil 5	1				46					2			49
Total	75	23	44	1	92	6	8	1	1	3	1	1	256
CR526T/ 1	8	3	14	1		1					1		28
2	13	3	4	2			1						23
Total	21	6	18	3		1	1				1		51
CR526R/ 1	1	2											3

*Figures are all numbers of identifiable specimens for reasons discussed in Chapter 9 (Technical Considerations: Quantification).

particular faunal assemblage, four factors are considered: (1) the depositional context, (2) fauna found in the same depositional context but not associated with tools or other evidence of human activity, (3) breakage patterns common to bone deposited by scavengers or predators (cf. Binford, 1981), and (4) fauna in the archaeological site in question.

Within any given depositional environment, in this case a stream floodplain, first determine what animal taxa occur in non-archaeological context; these are the natural component of a floodplain. Next, assess the numerical relationships among taxa in this context to determine the natural proportions of animals expected to occur in the floodplain environment. Finally, consider bone breakage patterns to establish the expected natural form of the archaeofaunal assemblage. This is the natural fauna of the floodplain environment: the kinds, proportions and forms of faunal remains that occur in the apparent absence of human activity. Now, to determine the cultural component, subtract the component from the complete archaeofaunal assemblage. The remainder are artifacts, hence cultural bone.

At 10CR334, Soil II contained no lithics or features, which I take as an indication that the faunal remains occurring in that stratum are representative of the natural component in the floodplain environments of the Project Area. Ground squirrel are numerous in this stratum and, except for a few gopher elements and a bighorn sheep skull (calvarium of a large male deposited in a sandy depression beneath the soil horizon), comprise the entire collection. Nearly all bones are complete. Thus, the natural component is complete bones of ground squirrels and gopher with bighorn sheep present but rare.

The faunal assemblage in Soils 1 through 4 differs considerably. Ground squirrels are usually common here as well, and gopher is present in one soil, but sheep is abundant, along with pronghorn. Bison, porcupine and cottontail also occur with some

consistency. Most ungulate bones have been shattered. Bison, pronghorn, porcupine and cottontail can all be considered as artifacts, because they are common in cultural layers, but absent in natural context. Most bones of bighorn sheep, which are abundant in cultural layers but rare in non-cultural, are probably present due to human activity also. Taxa that are only sporadically represented in cultural layers and may be absent from the Soil V assemblage because of sampling error, are unassignable.

At 10CR526T, there is no basis for comparison between cultural and non-cultural layers, and I will assume that the same taxa are cultural here as at 10CR334. Marmot may or may not be cultural in either case, but I shall treat it as cultural in the discussions of scheduling.

Among the cultural bones in all occupations, one or another species of ungulate (bighorn, pronghorn, bison) is always the most plentiful. When counts of these three taxa are combined by time period and converted to percentages (Figure 37), changes in exploitation are apparent. In Period 4, bighorn (Ovis canadensis) is numerically superior to the near exclusion of pronghorn (Antilocapra americana) and bison (Bison bison). Pronghorn rises in dominance in Period 5, while bighorn sheep remains important and bison is nearly absent. By Period 6, bison rises to near equivalency with bighorn sheep, matching a sharp decline in pronghorn abundance. Differences in taxonomic abundance between Periods 4 and 5, and 5 and 6 are both significant ($\chi^2 = 11.989$ and 37.07 respectively, $p < .01$). In spite of this statistical support for the dissimilarity among time periods, two problems prevent us from readily accepting these changes in resource exploitation as real. First, the numbers of each taxon are exceedingly small. Second, the qualification measure I use (NISP) assumes independence of individual elements when in fact interdependence of some elements in each assemblage is probable (see Chapter 9). Taken together, these problems compromise the value of χ^2 as a measure of difference (Grayson, 1981b) and call into question the reality of the difference itself. In this case,

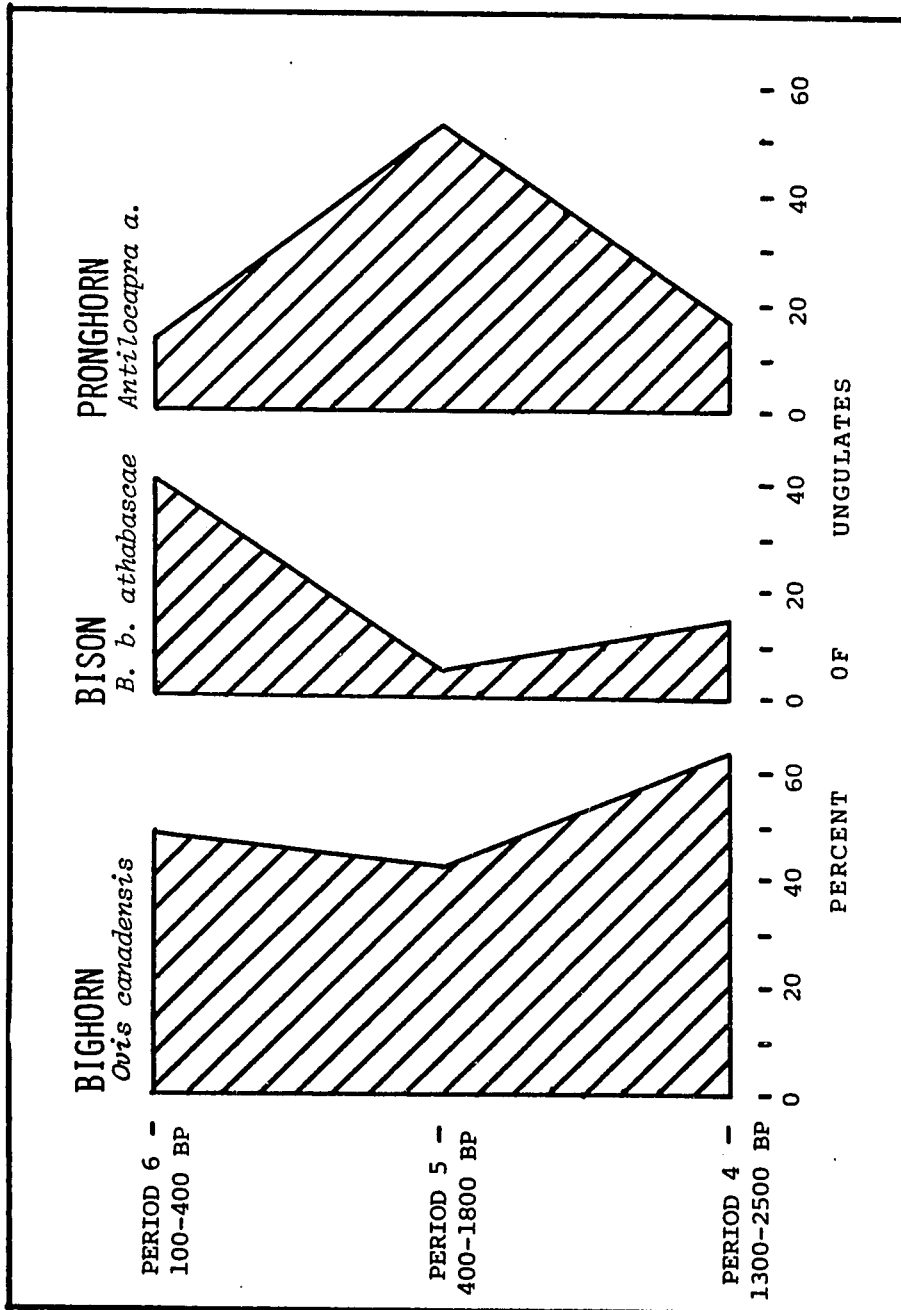


Figure 37. Artiodactyl taxa recovered from buried occupations attributed to Time Periods 4, 5 and 6. Actual ages of occupations are presented in parentheses below the time range for each time period.

neither problem is soluble at present. Independence of elements can rarely be demonstrated (Grayson, 1979a, b, 1981a, see Chapter 9) and without further excavations I have only the present faunal assemblage with which to work.

However, the pattern of change in resource exploitation indicated in Figure 37 is not only evident in the collective figures of Figure 37, but is also evident to varying degrees among individual assemblages (Table 55). Bighorn sheep dominates both Period 4 assemblages; pronghorn is superior in numbers in all three occupations of Period 5; and the high frequency of bison in Soil 1 of 10CR334 is reflected in admittedly minimal data from the Period 6 component of 10CR526. What these data indicate is that although samples are small, the change in ungulate exploitation, from bighorn sheep to pronghorn and sheep, to sheep and bison, is probably real and not a product of sampling error.

Seasonality: The Temporal Niche

The time dimension of the human ecological niche is calculated from the archaeological record using various methods of seasonality determination (cf. Chaplin, 1971; Monks, 1981). Two of these measures, tooth eruption and wear and presence-absence of species could be applied to the fauna summarized in Table 53. Seasonal information from both sources is minimal and in no case is it abundant enough to make firm statements. However, a consistent pattern is evident.

Tooth eruption and wear. This method of age determination is, in spite of its various drawbacks (cf. Monks, 1981:187-191), one of the most accurate means of assessing the ages of modern kills, and has been applied to several species of wild and domestic ungulates from archaeological contexts (cf. Chaplin, 1971; Chaplin and White, 1969; Frison and Reher, 1970; Nimmo, 1971). Archaeological application of this method is based on the assumption that rates of tooth eruption and wear are the same for modern and prehistoric

populations, an assumption that is probably valid at the time scale I am concerned with here. Only two mandibles were complete enough for this method to be applied, one a bison, from 10CR334, Soil 1, the other an infant pronghorn found in Soil 2.

Tooth eruption and wear sequences have been worked out for bison by Frison and Reher (1970) using specimens from predominantly fall kills. Consequently, use of their data requires a large degree of interpolation and results are to be used with some caution. The Soil 1 mandible had P2, P3, P4, M1 and M2 fully erupted and in regular wear. M3 had erupted and the first two cusps were in wear, but the third was unworn and not yet fully erupted. Frison and Reher (1970) state that by an animal's fourth fall, only the first cusp of M3 is worn, and by the fifth fall the second cusp is in wear and the third is fully erupted but not in wear. Therefore, the Soil 1 mandible represents an animal killed between the fourth and fifth falls, and considering the heavy wear on the second cusp of M3, probably in the later half of that period, in spring or summer of its fifth year.

The pronghorn specimen was identical in all respects to the mandible of a newborn observed in the Museum of Vertebrate Zoology, and was itself certainly either newborn or a mature fetus. Pronghorn fawns are born during a brief period each spring, the timing of which varies from place to place. In southeastern Oregon, most births occur between May 10 and 27, and in Wyoming the dates are June 5 to 15 (Einarson, 1947). Modern Pahsimeroi Valley females have their young during the last week of May and first week of June (Walter Bodie, personal communication). This specimen died in late spring.

Species presence-absence. Among the taxa in Table 55 there is only one which is only seasonally available, marmot; and it may or may not be cultural. All others could be killed at any time of year. Two species of this large ground squirrel inhabit the Pahsimeroi Mountains; M. flaviventris, and M. caligata, hoary

marmot. The latter is an inhabitant of alpine meadows and is half again larger than its lower elevation relative. Most of the marmot elements were skull parts from mature individuals and all were equal to or smaller than the comparative specimens of M. flaviventris to which I had access. None approached the size of M. caligata. The marmot from 10CR334 and 10CR526, therefore, is most likely to be from the smaller M. flaviventris that in both cases occupies nearby talus slopes.

Like most ground squirrels, marmots are only active for a few months, aestivating and hibernating for most of the year. They begin to emerge from their dens as soon as warm weather begins to thaw the ground, usually late March, and return in August or September when their forage has dried up and temperatures begin to drop (Bailey, 1936; MacClintock, 1970). Unless people were willing to dig through interlocking boulders to extract them, these animals must have been killed during their late spring to late summer active periods. Marmota is present in three occupations, Soil 3 at 10CR334 and both levels of 10CR526T.

Seasonality data, sparse as they are, give no reason to suggest that there was any change in the time dimension of the human niche during Periods 4 through 6. Evidence from ungulate ages and the presence of Marmota favor a late spring - summer period of habitation. These data in no way preclude habitation during other seasons, however, since most taxa are continuously available.

Summary: Relating Changes in Adaptive Patterns to Resource Utilization

Faunal and floral remains were excavated from two sites of the Lithic Tradition, 10CR334 and 10CR526, seven occupations in all, and have shown that three ungulates, bison, sheep and pronghorn dominated human resource niches during Periods 4, 5 and 6. These data also show that changes have occurred in the relative abundance of the three taxa, but the seasons of site use appear to have remained constant. I now use these findings to test two hypotheses:

(1) changes in adaptive pattern coincide with and can be related to changes in resource utilization, and (2) the change in adaptive pattern is not related to resource use.

Changes in human patterns of adaptation as reflected in artifact distributions do coincide with changes in the utilization of biotic resources during the latter part of the Lithic Tradition. Larger groups of people, hunting in open plains with large projectile points and in the canyon-stream habitats with smaller weapon tips have given way to small social units hunting almost exclusively with small projectile points in the canyon-stream habitat. At the same time, settlement diversity has declined. Coinciding with these changes is a shift in preferred species of ungulates, from the smaller bighorn sheep and pronghorn to the immense bison.

Land use patterns definitely reflect changing hunting strategies, with a high proportion of isolated tools being projectile points. Since various forms of stone-tipped projectile were unquestionably used for killing ungulates throughout North America, then there is a probable relationship between projectile point distributions and ungulates. Likewise, the change in sizes of social units using the Project Area may be associated with the shift in hunting technologies and therefore with the kind of animal being sought.

That such relationships exist can be demonstrated by taking into account the ecology of each ungulate taxon along with the techniques some Native American peoples found effective in hunting it. I shall consider five variables in the following discussions: (1) mode of defense, (2) drinking behavior, (3) annual variations in herd size, (4) habitat, and (5) hunting techniques effective with each ungulate and the group sizes necessary to their execution.

Antilocapra

Pronghorn are gregarious dwellers of treeless, flat country, but they may also be found high into the alpine zones of mountains where access is possible through open slopes. With limbs adapted

to running over level plains, and with speed and superb eyesight as their primary means of defense against predators, they avoid rugged terrain and brushy or forested habitats. Feeding usually takes place in areas where at least one herd member can find a clear, unobstructed view of the countryside (Van Wormer, 1968).

In winter, pronghorn congregate in herds of several hundred individuals in windswept areas where forage is clear of snow. Herds of several thousand have been reported, but now rarely occur. When the thaw begins in March or April herds disintegrate into sexually segregated bands. Female groups average around a half dozen individuals, while male bands number 15 to 20. When her fawns are about to be born in late May or early June, each female leaves the group for a period of around three weeks (Van Wormer, 1968) after which she and her two fawns join a nursery herd of up to several dozen animals (Einarson, 1947; Skinner, 1922; Van Wormer, 1968).

In late September or early October male herds break up and begin the task of attracting females into harems for the rutting season. Mating groups may reach twelve individuals, but far smaller harems are the rule (Einarson, 1947). By late fall, large winter herds have begun to re-form.

Pronghorn are browsing animals well adapted to the semi-arid steppes of North America. They are not obligatory consumers of free water, and may spend their entire lives without taking a drink (Van Wormer, 1968). In summer, when some individuals do drink, they may make single daily visits and are often habituated to specific watering spots (Frison, 1978). They may, however, drink only occasionally at irregular intervals days or weeks apart. In fact, these animals often seem to avoid water, crossing streams at top speed and running for some distance before stopping to look back (cf. Skinner, 1922). Heavy brush and timber are also avoided, except perhaps in winter. In the Pahsimeroi Valley, horn sheaths (shed in winter) and the skeletons of winter-killed individuals are common near wind-swept canyon mouths, but are no more abundant along bands of riparian brush than along terrace escarpments up to a

kilometer from water. Shelter, not water, seems to be the important variable here.

Inhabiting home ranges, pronghorn live their entire lives in small but seasonally variable territories and even in winter rarely move far from home (Van Wormer, 1968). They are also creatures of restricted daily habit, often bedding, feeding and drinking at the same locations.

The behavior of pronghorns makes them easy to hunt by a variety of techniques. An individual can stalk a herd or can conceal himself in open country and attract these intensely curious animals with a fluttering piece of skin or cloth. Frison (1978) states that they can be easily ambushed at watering holes, but the pronghorn's tendency to go for long periods without water would make this strategy less reliable than the others.

Because of their gregarious nature and the near year-round occurrence of herds of varying sizes, these animals are amenable to communal procurement. Great Basin Shoshone and their mountain neighbors commonly hunted pronghorn by driving herds into corrals constructed for the purpose and either shooting them or simply running them to death (cf. Egan, 1917; Liljeblad, 1972; Regan, 1934; Steward, 1938). Pronghorn drives took place in winter during the 19th century in the lower Pahsimeroi, near the town of May (Steward, 1938). Relays of horsemen are also known to have chased herds in circles until the animals dropped, both on the plains (Wilson and Driggs, 1919) and the Lemhi Valley of Idaho (Thwaites, 1905). Both techniques required large groups of people and an organizational structure both to construct corrals, when used, and to control the herds. According to Steward (1938), large winter drives often severely depleted pronghorn populations. Because of their gregarious tendencies, however, these animals could have been taken by communal effort through most of the year, at times when smaller segments of the population could be killed with little or no long term effect on species numbers.

Ovis canadensis

In some respects, bighorn sheep are the opposite of pronghorn. They are grazing mammals inhabiting rugged, treeless terrain and are rarely found on level, open ground far from some rocky escape route. In other ways, however, the behavior of these two species is much alike.

Bighorns are also gregarious, wary animals with keen eyesight. Throughout most of the year, herds of rams and ewes live near each other but move about as separate groups. The species has been studied most intensively in Canada's Banff National Park (Geist, 1971), an area somewhat similar to the Pahsimeroi Mountains. In late September and early October, large herds of rams congregate in pre-rut pastures among ewes and juveniles which are entering their low elevation winter ranges. By the end of October, the immense ram herds have dispersed to habitual rutting grounds where they breed with ewes from summer ranges other than their own. By the last part of December or early January, rams return to the pre-rut pastures to winter over among females and young. A second major migration for ewes occurs in early spring, when they and the rams move to spring home ranges, often at higher elevations (cf. Smith, 1954). These groups again break up in early summer, with the pregnant females migrating to lambing areas, where they stay the summer in nursing herds, while the rams, barren ewes and juveniles go to their own summer ranges.

Ewes migrate as a group and rarely deviate from their habitual migratory routes. Rams move about more freely, migrating in small groups or as isolated individuals from pasture to pasture. Their movements are also habitual, but are apparently somewhat less rigid than those of the females. Nursery herds and rams do not interact except during rut.

Bighorns generally avoid open country and forests (Geist, 1971; McCann, 1956) and in the Yellowstone area have not been observed drinking water from streams, apparently satisfying their needs by

eating snow or drinking from small ice-melt pools on their summer ranges.

Habitual in their patterns of movement, and with nursing herds of up to 70 and congregations of rams often as large or larger, big-horn sheep are prime targets for communal hunting through ambush or by driving animals into enclosures to be dispatched (e.g., Frison, 1978:256-270). They can also be stalked individually, but this is a difficult proposition in warm seasons because the animals are then alert, skittish and capable of seeing movement from great distances. The stalk would be more successful in colder months, when the animals' lowered metabolism rate makes them sluggish (W. Hickey, personal communication). Liljeblad (in Miller, 1972) describes the Tukudeka Shoshone technique of hunting individual sheep by driving them over precipices onto set spears.

Bison

The subspecies of bison inhabiting mountainous terrain of Central Idaho was probably the mountain or wood bison, B. bison athabascaae. This animal was slightly shorter, darker and more massive than the more populous plains bison (B. b. bison) and quite different in behavior. I have recovered two bison skulls from the Project Area, both bulls. One was a young animal, probably in its third year; the other a mature individual. The latter specimen measures .66 m across the horn cores, a size well within the range for the athabascaae subspecies, but exceeding the size of the largest recorded members of B. b. bison (Skinner and Kaisen, 1947). This skull came from the surface of sediments at Bisonsweh Pond and dates within the last several hundred years (Chapter 10).

Bison of this mountain race do not form the large herds common to B. b. bison of the plains, but live instead in bands of from 5 to 30 animals. A half dozen to a dozen individuals is the most common group size (Dary, 1974; McHugh, 1972). Explorers described this animal as difficult to find and hunt, and capable of negotiating surprisingly rugged terrain for a creature of its bulk

(Dary, 1974). Little else is known about the subspecies, which became extinct in the United States by the 1890's. Bison of Canada's Wood Buffalo National Park, although descended from B. bison athabasca have recently been interbred with the plains bison and their behavior may therefore differ from the ancestral pattern.

Unlike sheep and pronghorn, bison are heavy drinkers and often rest and graze in and around watering places (McHugh, 1972; Roe, 1951). With poor eyesight, these animals rely primarily on keen senses of smell and hearing to detect enemies (Dary, 1974). Plains bison were hunted communally using drives into corrals or to jumping-off places (e.g., Frison, 1978 and many other works), but except for rare cases (cf. Butler, 1971) wood buffalo probably did not congregate into groups large enough to make such drives possible. Frison (1973, 1978) has suggested, and Reher (1977) has presented convincing evidence, that a critical number of bison was necessary before communal hunting became sufficiently productive. With the large number of people needed to keep animals moving in the direction of a trap or jump and the likelihood that at least some of the prey might escape, a large number of bison would have to be present to make the effort profitable. Alternate hunting strategies, such as the ambush on trails or near watering places, or driving of individuals into deep snow, both used by Tukudeka Shoshone (Liljeblad cited in Butler, 1971), would have been more effective means of preying on this animal.

Summary of Lithic Tradition Resource Use

Among the three species of ungulate found in sites 10CR334 and 526 we are really looking at two kinds of creature in terms of behavior and effective hunting strategy. On the one hand are the small, gregarious open country pronghorn and bighorn sheep which have excellent eyesight for defense and rarely visit streams for water. Both species occur in large enough herds throughout most of the year that communal hunting would be effective. On the other

hand are the mountain bison; large, water-consuming animals which reside near water holes and rarely gather in herds large enough to be communally hunted. With their weak eyes and penchant for staying near riparian brush, these creatures are most easily taken by single hunters waiting in ambush or small groups chasing them into deep snow and, potentially, mud.

There is, thus, a plausible basis for a connection between animals hunted and changes in group size and hunting technology. Large groups hunting small ungulates in open ground (pronghorn in the plain, sheep in rugged land) change by 400 BP to small groups taking bison from stream-side ambush.

Summary

Data on the time and resource niches of the Pahsimeroi Valley's human inhabitants have been obtained from the land surface, in the case of the Metallic Tradition, and from seven buried occupations of the Lithic Tradition. In both cases, the results support Hypothesis 1 (changes in adaptive pattern are related to resource use) over the converse, Hypothesis 2 (the change is not related to resource utilization). Although the time niche may have remained stable, changes in the utilization of resources occurred during both traditions which were coincident with and are plausibly related to changes in adaptive patterns. The change in settlement size and hunting technology between Periods 5 and 6 coincides with a decline in the importance of highly gregarious small ungulates, pronghorn and mountain sheep relative to the large, more solitary mountain race of bison. Likewise, the disappearance of large, permanent settlements associated with intensive pastoralism and their replacement by small, temporary camps and intensified hunting activity is reflected in the ungulate fauna. Before +2 BP, domestic animals, principally cattle, dominate the faunal assemblages from Metallic Tradition contexts, but thereafter, a wild fauna is more important.

CHAPTER NINE

History of the Pahsimeroi Valley Ungulate Fauna

In the preceding chapter I have shown that ungulates dominated the resource niches of the Upper Pahsimeroi's human inhabitants for the past 2500 years, and that changes have occurred in the presence and proportionate abundance of the taxa comprising those niches. Bison use increases relative to pronghorn and mountain sheep between Periods 5 and 6, and the diverse domestic and wild fauna exploited during Periods 7 and 8 becomes a pronghorn dominated assemblage in Periods 9 and 10. These changes in the resource niche coincide with and are plausibly related to changes in adaptive patterns.

To ascertain whether these changes have been caused by changes in the local climate or by technological or other cultural changes, we must now consider two more competing hypotheses (Figure 1). Each change in the resource niche occurred either as a consequence of selective pressures generated by shifts in the people's effective environment, or because factors internal to the cultural system altered the relationship between people and a stable environment. In this instance, the effective environment has always consisted of populations of ungulates, wild and domestic, that the people were cropping to meet their nutritional needs. If the effective environment hypothesis is the better one in either of the cases cited above, there should be congruous changes in the taxonomic composition of the local ungulate community coincident with or just preceding the change in human adaptation. The increase in bison use in Period 6 should coincide with or follow an increase in the abundance of bison to bighorn sheep and pronghorn and the disappearance of domestic sheep and horses and the overall reduction in the importance of domestic relative to wild ungulates between Periods 8 and 9 should be mirrored by the natural populations of the animals.

Only if the data fail to support one or both of these hypotheses is the cultural cause hypothesis the better alternative.

To test these hypotheses I made paleontological collections in the Project Area and used them to construct a history of Pahsimeroi Valley ungulate faunas from 2300 BP to the present. The bones came from two sources: (1) Buck Creek Cave, a small limestone cavern which had not been extensively used by people and (2) the surfaces of sample transects. The Buck Creek Cave assemblage spanned the Holocene, but failed to provide the detail required to test relationships between the effective environment and human adaptations during the last 100 years. Surface collected skeletal remains remedied this deficiency. In this chapter I present the techniques used to acquire these collections, evaluate the sufficiency of my data for providing an accurate picture of past populations of animals, and present the results of my analyses.

Data Collection

Buck Creek Cave

Buck Creek Canyon is a narrow-limestone defile that drains the northwest side of Spring Hill, contributing seasonal runoff to Doublespring Creek. The cave (10CR525) is located at an elevation of 7200 feet in a small outcrop on the canyon's southeast wall approximately 100 m from the mouth (Figure 38). The setting is ecotonal, with montane forest, steppe and transition zones forming a complex floral mosaic. A band of Douglas fir (Pseudotsuga menziesii) forest crosses before the cave mouth, steppe occurs above and 10 m below along the canyon floor, and stands of mountain mahogany (Cercocarpus ledifolius) dot the opposite canyon wall. Of the various plant communities commonly found at this altitude, only the riparian zone is not visible from the site. Riparian habitat does, however, occur in isolated patches less than 0.5 km south and to the north along Doublespring Creek. With its steep, rocky terrain and patches of steppe flora, the canyon is mountain sheep

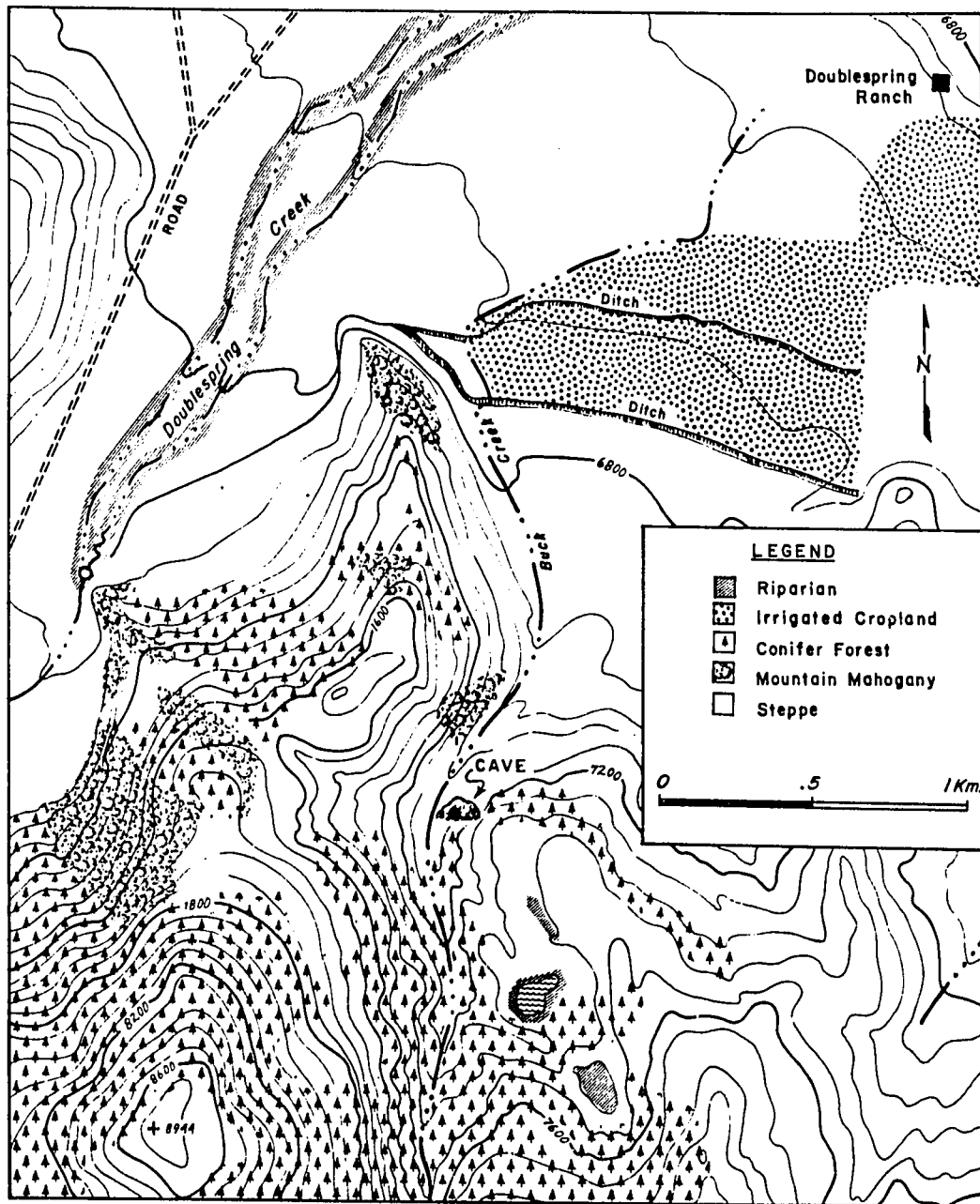


Figure 38. Buck Creek Cave and vicinity.

habitat, but other ungulates would be at home nearby, on the more level ground of Doublespring Canyon.

The site is a narrow cavern formed by dissolution and frost ablation acting on a contact zone between dipping beds of medium gray Mississippian limestone (Bond, 1978; Mapel et al., 1965). There are two openings interconnected at their ceilings by a narrow crevice 3 m long. The larger chamber is 2.5 m high and 2 m wide at the mouth, and becomes progressively lower and wider toward the back (Figure 39). Roof and walls form an inverted V tilted sharply to the southwest, with the apex forming the crevice connecting this room with the much narrower second chamber. The paleontological sample came from the floor of the larger chamber, which slopes downward from the extensively disturbed rear of the cave toward the mouth, where a relatively undisturbed, level area is found. Outside, a 45 degree slope drops 5 m to the canyon floor; there is no berm.

Floor sediments are a combination of carnivore scats, rat dung, plant fragments and bones, although aeolian silts and limestone roof-fall have contributed to this largely biogenic deposit. Bushy-tailed woodrats (Neotoma cinerea) nest in the crevice between chambers and are responsible for much of this debris and at least part of the disturbance in the cave floor.

Excavation. After the cave floor had been mapped topographically (Figure 39), a unit was chosen for excavation to avoid the disturbed rear of the cave and the mouth, where water and frost action might detrimentally affect bone preservation. The 1.2 m x 2.0 m excavation block was laid out perpendicular to the cavern's long axis between 2.2 m and 3.4 m from the mouth (Figure 39). The unit was made unusually wide to anticipate the need to telescope pit walls and prevent the soft sediments from collapsing. Excavation proceeded by 10 cm arbitrary levels, but where clear stratigraphic breaks occurred, materials from each stratum were collected separately. Rodent activity was common, and where possible, the

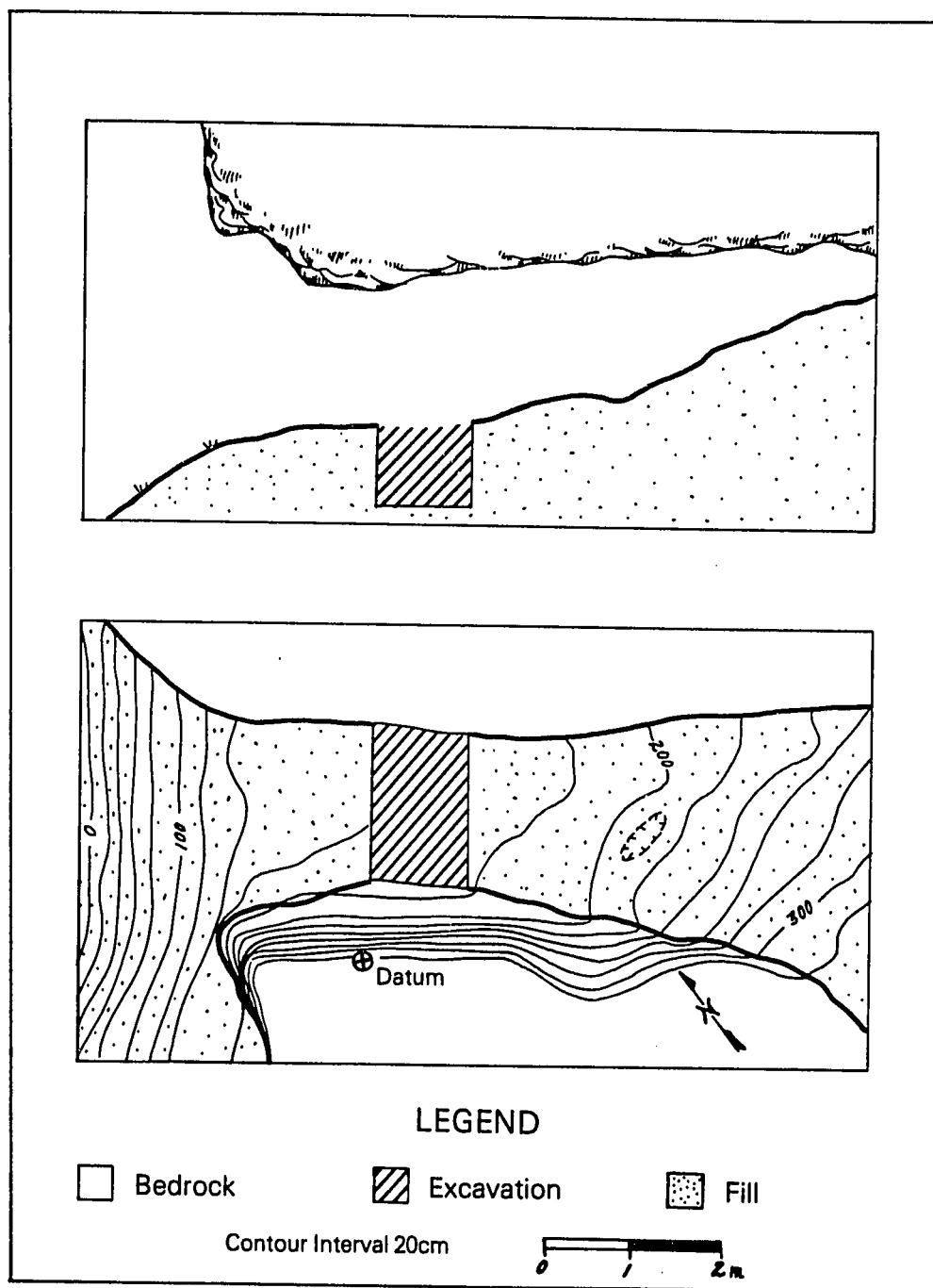


Figure 39. Profile and contour map of Buck Creek Cave, showing the location of the sample unit.

fill of rodent burrows was discarded to reduce the problem of vertical mixing. Matrix was passed through 1/8 inch mesh and all material remaining in the screen was bagged and taken to the laboratory for sorting. Finally, a 30 cm x 30 cm portion of each 1 x 1.2 m horizontal unit was saved from each level to obtain samples of faunal and floral remains that might slip through the screens (cf. Thomas, 1969).

Excavation was discontinued at a depth of 1.0 m, where the slanting cave wall had made the pit too narrow for work to proceed effectively (Figure 40).

Stratigraphy. The deposit lacked distinct strata in the sense of obvious layering, and appeared to be a uniform deposit in which compaction and decay had rendered deeper deposits more moist and firm than those found nearer the surface. There were, however, some breaks in the otherwise massive matrix, distinguishable from each other by texture, color and a more rapid than usual gradient of compaction. These strata are Units I, II and III. Recognize that, although shown as distinct layers in the profile (Figure 40), these deposits actually intergrade in most areas.

Unit I extends from the surface to 80 - 90 cm and consists of dry rat dung, organic and inorganic dust, plant macrofossils, bones and fragments of limestone up to 7 cm across. Relative decay of fecal pellets and wood was used as a basis for subdividing this unit into three substrata. Ia consisted of fresh dung and dry, unrotted plant fragments extending from the surface to 5 - 10 cm and occasionally as deep as 15 cm. Intact carnivore scats were present, though not numerous. Unit Ib, to 30 - 35 cm, included dust, partially decayed plants and dung, and Ic consisted largely of loose, dry organic dust. Rooffall was never common in Unit I, but was most abundant from 10 to 35 cm.

Unit II was a highly localized, damp, yellowish gray silt found below Unit Ic and in crevices and basins in the cave wall between 70 and 90 cm. This stratum was nearly free of stones and

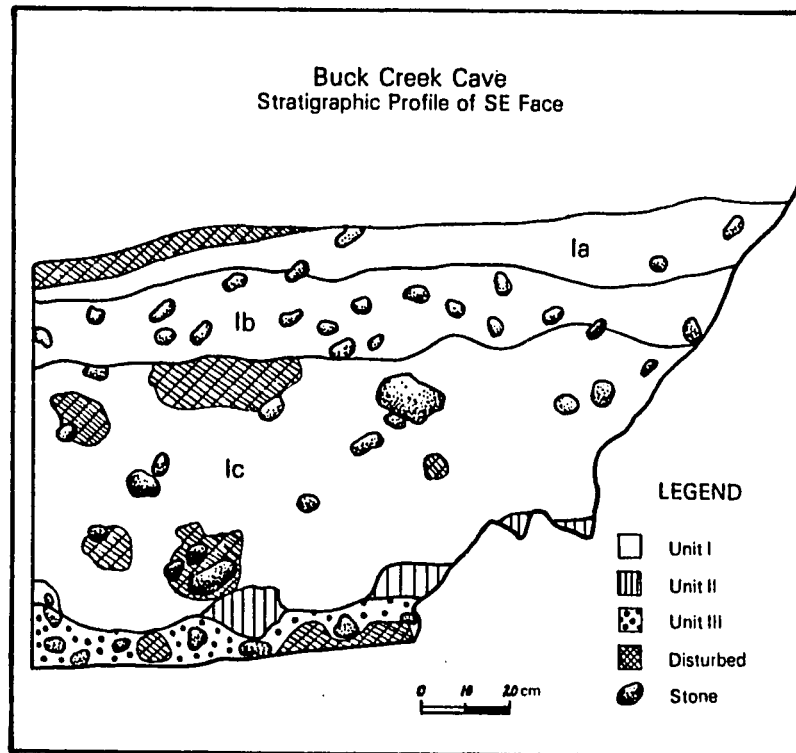


Figure 40. Stratigraphic profile of the southeast face of the excavation unit in Buck Creek Cave.

contained no uncharred rat feces or plant remains. Apparently, Unit II material had been deposited in crevices above 80 cm long before the fill had reached crevice height. This unit appears to be a damper, more decayed example of Unit I, with the yellower color indicative of a lower organic content and higher amount of moisture. Unit I intrudes into II over 60 percent of the cave floor, probably because of rodent disturbance. This intrusive material was removed from the bone sample summarized below.

The lowest stratum, Unit III, is an increasingly compact, calcium carbonate-cemented, grayish yellow clayey silt. Rockfall is most abundant in this stratum, which extends from 90 cm into unexcavated deposits.

Dating. Cave deposits were dated with a model of sediment compression based on radiocarbon assay and dendrochronology. Samples of charred organic matter, mostly rat dung and Douglas fir wood were collected from the screen residue of each arbitrary level and from charcoal concentrations found at various depths in Unit I. Four of these samples were submitted for Carbon 14 dating, two to the Laboratory of Radiochemistry at the University of Washington (UW 430, UW 431) and two to the Radiocarbon Dating Laboratory at Washington State University (WSU 1830, WSU 1831). The latter two samples were very small and could be dated more accurately by the WSU laboratory, which has better shielding and more experience with enhancement techniques.

Sample UW 431 came from a lens of burned material between 46 and 50 cm below surface, but the remaining samples were bulk carbon from the three deepest arbitrary levels. Samples UW 430 and UW 431 are from Unit Ic, WSU 1831 is from Unit II and WSU 1830 from Unit III. A single tree-ring date was read from a large, axe-cut chip of Douglas fir from Unit Ia. Only four of the samples could actually be dated; WSU 1830 was too small to produce enough CO₂.

A compression model for Units I and II was calculated from the four dates using a least squares regression (Model 1, cf. Thomas

1976), comparing depth (X) against age (Y). The depth for the sample from 46 - 50 cm was therefore plotted as 48 cm; for 70 - 80 cm, 75 cm; and for 80 - 90 cm, 85 cm. Wood chips associated with the dendrochronologically dated sample were found between 5 and 10 cm, and the maximum, 10 cm depth was used because it represents the earliest occurrence of this phenomenon. So that tree-ring and Carbon 14 dates would be comparable, carbon dates were corrected to calendric ages using the curve presented by Ralph and Michael, 1974 (from Suess, 1970); (Table 56).

Table 56. Carbon 14 and Tree-ring Dates from Buck Creek Cave*

Sample No.	Material	Depth	Age in C14 years BP	Corrected Age in years BP
None	wood chip	10 cm	—	46
UW 431	charred wood and dung	48 cm	1246 $\pm$ 110	1200 $\pm$ 110
UW 430	charred dung	75 cm	2338 $\pm$ 150	2360 $\pm$ 150
WSU 1831	charred dung, some wood	85 cm	4599 $\pm$ 150	5200 $\pm$ 150
WSU 1830	charred dung	95 cm	too small	—

*Carbon dates are calculated from the Pennsylvania half-life of 5770 years and their approximate calendric ages, based on the Suess (1970) correction, are also shown. Depths for radiocarbon dates are averaged (see text).

Because sediments appeared to be compressed and the time interval represented by a 10 cm level near the bottom of the deposit was probably far greater than that represented near the surface, a semi log function was deemed most appropriate as a model of sediment deposition rate. The resultant equation

$$\text{Log}^{10} Y = 1.71 + .0273X \quad (\text{Equation 1})$$

had a correlation coefficient of 0.997 and a variance of 0.995. Although the unusually high correlation is partly due to the small number of sample points, Equation 1 nonetheless confirmed my suspicion that sediments were progressively more compacted with depth. The resultant curve (Figure 41) was the basis on which the ages of bone samples were calculated (Table 57).

Table 57. Ages of Faunal Samples Obtained from Buck Creek Cave*

Sample Depth	Calculated Age in years BP	Actual Age (C14 and tree ring) in years BP
0 - 10	25 - 65	+25 (surface) to 46 BP (tree-ring)
10 - 20	65 - 125	
20 - 30	125 - 260	
30 - 40	260 - 460	
40 - 50	460 - 780	1200 $\pm$ 110 at 46 - 50 cm
50 - 60	780 - 1360	
60 - 70	1360 - 2340	
70 - 80	2340 - 4040	2360 $\pm$ 150
80 - 90	4040 - 6970	5200 $\pm$ 150
90 - 100	6970 - 12,000*	

*Based on the regression formula $\log^{10} y = 1.710 + .0237x$. Tree-ring and radiocarbon dates are compared against calculated ages in the righthand column.

**Because Unit III is different from upper strata in its greater content of roof fall, the applicability of Equation 1 in this instance is uncertain.

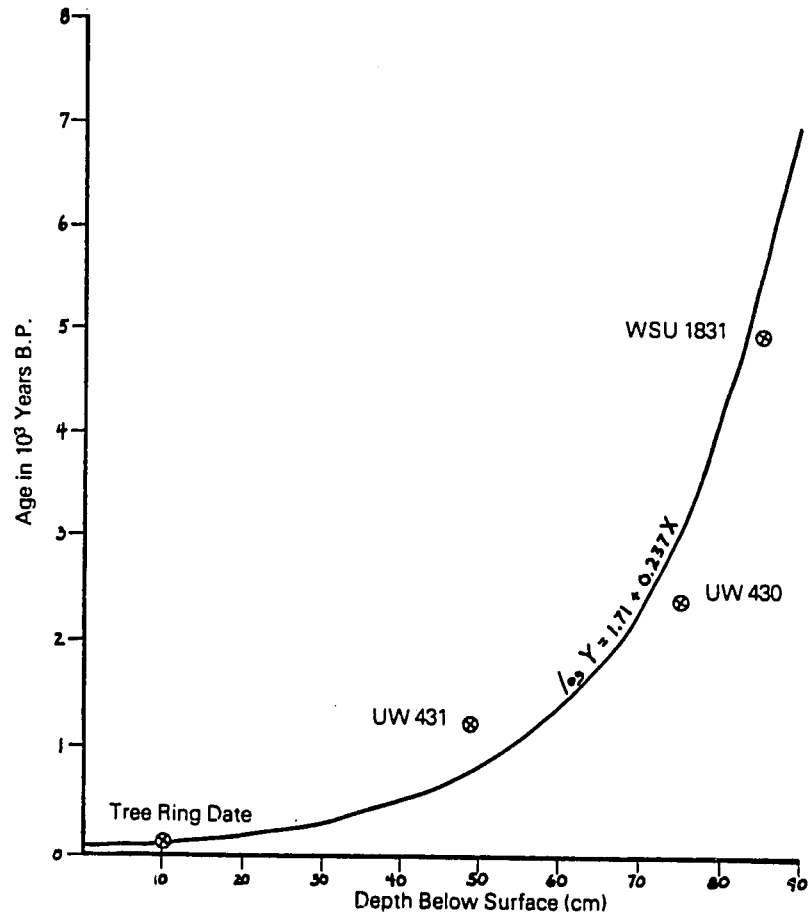


Figure 41. Deposition rate for deposits in Buck Creek Cave. Compare actual sample ages with predicted dates.

The Northeastern Valleys projectile point chronology (Chapter 6) provided an independent check on the model's validity. Two projectile point fragments from small, side-notched specimens of Historical Type S3 had been found in the 20 - 30 cm level. Dated elsewhere in the region to between 100 and 400 BP (cf. Ranere, 1971; Swanson, 1972) and in 10CR526R at 300 ± 20 BP, these artifacts are estimated by Equation 1 at 125 - 200 BP. This is well within their known age range.

Artifacts. If we are to use the faunal remains from Buck Creek Cave to measure changes in the presence and relative abundance of the ungulate taxa comprising the effective environment of human beings, it is imperative that those same people not be responsible for the cave's bone assemblage. The number of artifacts in the site can be used as a measure of human activity to show that people have made little use of this shelter during any time period.

There were 109 artifacts found in the approximately 2 cubic meters of deposit (Table 58). Although this may sound like a considerable assemblage, consider two additional facts: (1) they were deposited over a 2000 year period, (2) excluding wood chips, all but four are so small that they would have fallen through the conventional 1/4 inch screening used by archaeologists. In fact, 85 (97%) of the lithic artifacts are tiny chips of cryptocrystalline and obsidian with the thin platform, flat cross-section and narrow, ovate outline characteristic of flakes produced by pressure retouch. A few occur in each level to a depth of 70 cm. The only other artifacts are two broken projectile points (basal portions only), a cryptocrystalline flake 1.2 cm in diameter, a rifle cartridge (functional type M9) and wood chips. The wood chips are probably not in situ, considering the difficulty anyone would have swinging an axe in the cave, and have probably been collected from the nearby forest floor (where old stumps can still be seen) by woodrats.

There were no features; all charred debris in the cave, including four discrete lenses of burned debris, can be accounted

for as natural, caused by prairie fires, forest fires or spontaneous combustion igniting the woodrat middens of the cave floor.

Table 58. Artifacts Recovered from Buck Creek Cave, Listed by Arbitrary Level

Level	Flakes 1cm ²	Flakes 1cm ²	Projectile Points	Cartridge M9	Wood Chips	Total
0 - 10	4			1	20	25
10 - 20	3					3
20 - 30	16		2			18
30 - 40	15					15
40 - 50	11					11
50 - 60	26	1				27
60 - 70	10					10
70 - 80						0
80 - 90						0
90 - 100						0
Total	85	1	2	1	20	109

This small quantity of artifacts in all levels is indicative of brief, intermittent visits and human activity is thus unlikely to have had more than minor influence over the faunal assemblage found there.

Faunal and floral remains. Bone preservation was excellent in the neutral pH (7.1) of the cave matrix, and over 50,000 fragments from bird, mammal, fish and reptile were found in the small excavation unit. Many of the bones in Unit III had become mineralized, taking on a distinct cream to yellow color and a higher than normal

density. Specimens from Unit I were still in their original state, while Unit II was intermediate. These distinctions were used to separate Unit III bones from upper layers and remove them from the analysis, thus reducing the effects of mixing.

The bone assemblage resembles what Mellett (1974) calls a coprocoenesis. The majority of bone fragments from large rodents, leporids, carnivores and ungulates have rounded edges and surfaces etched by gastric acids, whereas smaller bones are usually found in their original condition. Bones from larger birds and mammals are also almost uniformly broken into fragments of less than four cubic centimeters, but the skeletal elements of small mammals and reptiles are often complete. The characteristics are common to bones that have passed through the alimentary canals of carnivores. Small bones, which move readily through the gastrointestinal tract remain unaltered, while the larger bones pass more slowly and are consequently etched to a great extent. Much of the bone accumulation of this site, therefore, probably arrived in carnivore scats.

Many fragments also show gnawing marks from rodent teeth along with etching and occur on nearly all larger bones that exhibit no etching. A noteworthy number of unetched, gnawed bones have exfoliated surfaces and must have lain exposed on the ground for years before being collected by woodrats.

Uncharred plant macrofossils, carnivore scats and packrat dung were common in the upper 30 cm of the deposit; bits of charred wood and dung occurred in all levels. Most of the plant fragments came from Douglas fir, sagebrush (*Artemisia* spp.) and various grasses. (Because these materials were not to be used to reconstruct a floral history of the area, they were not systematically analyzed.)

Surface Fauna

Most of the period encompassed by the Metallic Tradition (+25 to around 80 BP) was included in the upper two levels at Buck Creek Cave, and Periods 8 through 10 are represented only in the uppermost 10 cm unit. Consequently, data from the cave alone could not be

used to compare Metallic Tradition adaptations with their effective environments. To provide more detailed information on ungulate populations of the study area during the last century, data were gathered from ungulate skeletons found on the surfaces of archaeological survey transects. When bones were encountered during the pedestrian search of transects, notes were made on the location of the find, the element or elements present, their condition, and their taxonomic membership. If field identification was impossible, as with isolated bones or highly weathered specimens, fragments were collected and studied later. Only the bones found outside artifact aggregates were used in the study described in this chapter, to avoid confusing the human niche with the effective environment. Records were also made on large mammal remains found in the study area but outside survey transects and although unsystematically gathered, these data provide an important supplement to information obtained from the transects.

Dating. Relative degree of weathering was the criterion used to determine bone ages (cf. Behrensmeyer, 1978), with unweathered Class 1 fragments dating +10 - +25 BP; Class 2 to 20 - +10 BP and Class 3 older than 20 BP (Chapter 6).

Analysis

Identification

With the exception of those surface specimens which could be identified in the field, all identifications were made by comparison with skeletons from the Thomas Burke Memorial Washington State Museum, the Puget Sound Museum of Natural History, the Museum of Vertebrate Zoology at the University of California, Berkeley, and from the private collection of Dr. D. K. Grayson. I identified the mammals, and Dr. R. W. Casteel identified the fish; reptile and bird bones have not yet been studied.

Identification was taken to the least inclusive taxon possible, usually to genus. Ungulates and microtine mice were identified to species. Microtine identifications were based on dental characteristics, while the distinction between domestic sheep (Ovis aries) and the native bighorn sheep (Ovis canadensis) was based on measurements of weight-bearing bones. The maximum anterior-posterior and medial-lateral dimensions of weight-bearing articular surfaces of the humerus, tibia, radius, ulna and metapoidals were measured in all male and female specimens from both sexes housed at the Museum of Vertebrate Zoology, Berkeley. The resultant data demonstrated the clear size distinction between the two species. Specific identifications of Ovis were, thus, based on size of skeletal elements.

A major problem arose in the separation of Bison from Bos (domestic cattle) when Class 3 surface remains and the small bones of feet were encountered. Because the two animals are morphologically very similar, foot bones and small fragments of long bone which lack key landmarks are especially difficult to identify to the genus level. Where exact identifications could not be made, the designation Bos/Bison is used.

Technical Considerations

Quantification

The appropriate unit in which to quantify faunal remains has been a constant subject of concern to vertebrate paleontologists, especially those who have been working with archaeologically-derived faunas (e.g., Bokonyi, 1970; Casteel, 1976, 1977, n.d.; Chaplin, 1971; Daly, 1969; Grayson, 1973, 1978a, 1979a; Gilbert and Steinfeld, 1977; Hesse and Perkins, 1974; Perkins, 1973; Uerpmann, 1973; Ziegler, 1973; see also Shotwell, 1955). With few exceptions, two measures have been employed: the number of identified specimens per taxon (NISP, Chaplin, 1971) and the minimum number of individuals (MNI, White, 1953). Neither measure is without major

limitations and both have been extensively criticized (cf. Grayson, 1979a; Uerpmann, 1973; Ziegler, 1973).

NISP, simply the raw count of the number of individual bone fragments assigned to a particular taxon, has been the more heavily criticized of the two abundance measures. Of the many criticisms, those that relate to non-archaeological collections include: (1) the numbers of identifiable specimens differ between taxa and from one investigator to another for a given taxon (Gilbert and Steinfeld, 1977; Perkins, 1973; Shotwell, 1955, 1958), (2) use of the measure incorporates the assumption that bones of all genera are equally affected by breakage and by weathering (Behrensmeyer, 1978, Behrensmeyer et al., 1979; Casteel, 1971; Gilbert and Steinfeld, 1977; Perkins, 1973), (3) bones of various taxa will be differentially affected by recovery techniques (Casteel, 1972; Payne, 1975; Thomas, 1969; Ziegler, 1973), (4) the degree of skeletal completeness may vary between species, thereby skewing the counts in favor of taxa with less dispersed skeletons (Ziegler, 1973; cf. Shotwell, 1955, 1958; Thomas, 1971b), (5) as a result of problems one through four the measure may differentially exaggerate variations in sample sizes between taxa (Grayson, 1977b), (6) the measure assumes element independence, an assumption that must be demonstrated each time the unit is employed (Gilbert and Steinfeld, 1977; Grayson, 1973, 1977a, 1979a, 1981a; Hesse and Perkins, 1974; Perkins, 1973), and as a consequence, (7) NISP supports fewer statistical analyses than does MNI (Grayson, 1973, 1979a), (8) these difficulties all but invalidate any attempt at intersite comparison.

Of these criticisms only those associated with the interdependence of skeletal elements cannot be solved through controls in data acquisition or analysis. The interdependence problem is, however, nearly fatal to the use of NISP as an abundance measure (Grayson, 1979a, 1979b, 1981a). Unless one can demonstrate that, for a given site, each bone can be assumed to have been contributed by a separate individual, one's data on taxonomic abundance are open to the criticism that there may be no relationship between the

number of individual animals contributing bones to the sample and the quantities of taxa expressed by NISP.

MNI is decidedly less reliable than NISP, and its validity has been thoroughly refuted by Grayson (1973, 1978a, 1979a) and Casteel (n.d.). The most damning problems with this approach are: (1) numbers are differentially affected by methods of data aggregation (Grayson, 1973; Casteel, 1977), (2) values vary considerably depending on which calculation technique is employed (Grayson, 1979a; cf. Bokonyi, 1970; Casteel, 1975, 1976; Chaplin, 1971; Flannery, 1967; Krantz, 1968; White, 1953), (3) the measure is strongly affected by sample size (Grayson, 1978; Uerpmann, 1973) and is in fact a function of NISP (Casteel, n.d.).

Criticisms of the use of MNI as an abundance measure, especially the effects of sample size, clearly demonstrate that this measure is at best no more accurate an indicator of actual taxonomic abundance than is NISP, and because it is a function of NISP, is in fact likely to be less accurate. I therefore have chosen to use NISP in dealing with problems of taxonomic abundance at Buck Creek Cave, and will attempt to demonstrate that ungulate elements from the site can be treated as independent units. In the case of surface-collected fauna, the problem is moot. Skeletons and isolated bones were always widely separated, often by several kilometers and can safely be conceived of as separate individuals.

Reconstructing Faunal Communities

Grayson (1979b, 1981a) has observed that there are two basic approaches to the reconstruction of paleoenvironments using faunal remains: the taxa as attributes approach, in which the presence of various taxa is taken as indicative of particular ecological conditions (e.g., Grayson, 1977b; Guilday and Adam, 1967; Guilday and Parmalee, 1972; MacMillan, 1976) and the taxa as variables approach in which environmental events are inferred from changing abundances of various taxa (e.g., Butler, 1972b; Grayson, 1976, 1977a; Guthrie, 1968b; Harper and Alder, 1970). Each approach reconstructs the

composition of a faunal community as a first step, a critical point to which I return later. In the same article, Grayson presents a thorough critique of these approaches. Although his comments are specifically directed towards paleoenvironmental reconstruction from archaeologically acquired faunas, they are applicable to the reconstruction of faunal communities from any source.

Grayson (1979a, 1981a) argues that paleoenvironmental reconstructions based on the use of taxa as variables are unlikely to produce demonstrably valid results. In support of this contention he cites two compelling reasons: (1) the relationship between the abundance of a taxon in the paleontologist's sample and the number of animals that actually contributed bones to that sample is unknown and, in most cases, unknowable, and (2) the relationship between the relative abundances of taxa once living in the vicinity of a site and the quantitative relationships among taxa in the collection of bones actually deposited is also unknown and unknowable.

The first problem is a direct consequence of the inaccurate measures of taxonomic abundance available to the paleontologists. Because NISP assumes that each identified element has been contributed by a separate individual (Grayson, 1977a, 1979a; Perkins, 1964, 1973; Uerpmann, 1973) and MNI is a function of NISP (Casteel, n.d.) with additional problems related to the aggregation of recovery units during analysis (Grayson, 1973), the relationship between the number provided by either measure and the actual number of animals that contributed bones to the sample is in all but trivial cases, unknown (Grayson, 1979a, 1979b, 1981a). Only if it can be shown that each bone in the sample came from a different individual can this difficulty be surmounted.

Relative abundances of taxa accumulated in a paleontological deposit cannot be assumed to accurately represent the quantitative structure of the living community that contributed to the deposit because the mechanisms that effected the accululation cannot be assumed to have selected a random sample of animals existing in the area. Most predators, which are common contributors to some kinds

of paleontological sites (Mellett, 1974; cf. Klein, 1975) do not collect species in direct proportion to their numerical abundance, but are in most cases highly selective. Moving water, another common bone concentrating mechanism has access only to the bones of animals that die in or are dragged into its path, and will often sort remains according to size, depositing them in distinct hydrologic environments (cf. Wolff, 1973).

If the relative contributions made to a bone assemblage by different depositional mechanisms varies through time, the numerical relationships between taxa deposited in the assemblage may also change, even though the structure of the living community remains constant. Taphonomic studies (Efremov, 1940) sometimes can help identify the depositional mechanisms responsible for a faunal assemblage (cf. Mellett, 1974; Voorhies, 1969; Wilson, 1960) and might also be an effective way to assess whether the mechanisms have changed through time. Nevertheless, there is no way of altering the basic fact that paleontological collections are not small scale mirror images of living communities of animals.

Problems associated with treating taxa as attributes are far less severe (Grayson, 1979b, 1981a). Although the robustness of this method is diminished by minor difficulties such as long distance transport, poor stratigraphic resolution, stratigraphic mixing and sampling error, this simpler approach is free of major handicaps. Grayson therefore advocates that taxa be treated not as variables, but as attributes when paleoenvironmental reconstruction is the goal.

Aside from the relative merits of either approach, one point remains. If the students of extinct faunal communities are restricted to the use of taxa as attributes, the only phenomena that can be discerned from the fossil record are changes in taxonomic composition. More subtle changes in the numerical relationships among taxa are completely masked. A change in the taxonomic composition of an ecosystem often requires a major change in local climate, a rare event on the short time scale. During the Holocene

of western North America, for example, climates undergo marked change between 9000 and 7000 BP, after which climatic change consists primarily of minor fluctuations of varying duration and magnitude (Butler, 1972b; Grayson, 1977a; LaMarche, 1973; Martin, 1963). Changes in the taxonomic composition of many western faunas, therefore, occur only once, if at all during the Holocene (e.g., Grayson, 1977b, Gustafson, 1972). Consequently, if we are limited to treating taxa as attributes, rather than as variables, it is often impossible for us to investigate relationships between changing human adaptations and animal communities.

Certainly we will never be able to reconstruct the exact composition of paleofaunal communities by treating taxa as variables; the problems associated with that approach are inherent in paleontological collections and the measures of taxonomic abundance by which we count them. For the past 7000 - 9000 years, however, it is often the only means we have for studying change in paleofaunas, and it is essential that the inherent flaws of the approach be minimized so that reasonable approximations of faunal change can be obtained. This requires that three steps be followed: (1) the questions being asked of a paleontological collection must be clarified and reduced in scope, (2) the mechanisms responsible for the content of a bone assemblage must be identified and controlled for such that changes in the numerical relationships among taxa are not artifacts of variation in these mechanisms, and (3) the independence of each element in the collection must be demonstrated or at least a cogent, plausible argument must be made showing why elements can be conceived of as independent. If efforts to apply steps two and three fail, as more often than not they will, the probability that observed changes in the abundance of one taxon or a small set of related taxa are due to some phenomenon other than a changing environment is as high or higher than the probability that the changes are real. For example, Ziegler (1973) presents a comparison of Dama (roe deer) with Gazella (gazelle) at two paleolithic sites in the Middle East. Based on changing ratios of the

two genera, he draws conclusions about environmental conditions in the area over a period of several thousand years. Because he uses a single ratio in his analysis, Ziegler's results are as likely to result from sampling error arising from the interdependence of skeletal elements or variations in depositional mechanisms as to changing ungulate populations. This problem could have been minimized however, had Ziegler considered the behavior over time of sets of taxa which can be shown to have had similar habitat requirements to *Gazella* and *Dama*, but which are dissimilar in size and structure (Chatters, 1980b). The importance of differential size and structure is that change in depositional mechanisms, whether predators, scavengers or inanimate processes, is unlikely to have an equal effect on such distinct animals. If the relative proportions of taxa within one set exhibit the same behavior when compared with one or more other sets, the most elegant and parsimonious explanation for the changes is achieved by invoking an environmental cause. Grayson (1979b, 1981a) uses this kind of approach to overcome the deficiencies involved with treating taxa as attributes, but does not acknowledge its value when taxa are used as variables.

I shall follow the first alternative, Steps 1, 2 and 3 in the next few sections. Although the second alternative is certainly the more robust, and has been used effectively on the data from Buck Creek Cave (Chatters, 1980b), its application would be counter to my present purposes. If I must fall back on this alternative, I automatically deny the possibility that human activity may effect changes in faunal populations independently of environmental change.

The question. The most important aspect of any paleontological study is the nature of the questions to be answered. Voorhies (1969), Wilson (1960), Guthrie (1968a), Shotwell (1955, 1958, 1963) and others have sought to reconstruct extinct faunal communities, presenting taxonomic frequencies as reflections of the faunas from which the fossil assemblages were derived. As Grayson

(1979b, 1981a) has shown, this kind of precision is impossible. The question asked of paleontological data must be narrower in scope.

In working with the Buck Creek paleofauna, I am not interested in learning whether bison, pronghorn or sheep were present in the area; I already know they were (Chapter 8), hence the need to consider taxa as variables. Neither am I concerned with the actual taxonomic structure of animal populations, nor even with the relative abundance of species during any specific time period. Rather, I wish to determine whether there have been changes in the numerical relationships among a small set of ungulate taxa: Bison, Antilocapra, Bos, Equus, Ovis aries and Ovis canadensis. It is not important to know if, from time A to time B, the actual ratio of living bison to pronghorn changed from 1:3 to 3:1 nor if there were less bison than pronghorn in time A and more in time B. It is only important that there was a change in the abundance of bison relative to pronghorn.

By thus limiting the scope of my investigation, I minimize the most severe problem with paleontological data: it does not matter that the quantitative relationships between animals in the site fail to mirror those of the living community from which they came, only that changes among numbers of animals in one site, Buck Creek Cave, coincide with changes in the ungulate populations. However, the interdependence among skeletal elements and variations in taxonomic abundance that may be caused by changes in mechanisms of deposition compromise my ability to solve the problem posed here.

Depositional mechanisms: Taphonomy. Phenomena affecting bone deposition and survival in a paleontological site are the subject matter of taphonomy (Efremov, 1940), which has been of increasing interest to paleontologists and zooarchaeologists who seek to enhance the credibility of their conclusions (e.g., Behrensmeyer, 1978; Binford and Bertram, 1977; Butler, 1972b; Mellett, 1974; Voorhies, 1969). To develop an understanding of vertebrate

taphonomy, thorough studies are conducted into modern geologic and hydrologic processes (Voorhies, 1969), scavenger and predator behavior (Brain, 1969; Klein, 1975; Mellett, 1974) and patterns of bone weathering and breakage (Behrensmeyer, 1978; Mellett, 1974). The spatial and formal attributes of modern bones which have been affected by these various processes are then compared to characteristics of fossil specimens and the principle of uniformitarianism is applied to reconstruct the events associated with fossil deposition.

Concentrations of mammal bones commonly develop under three sets of conditions. They are either trapped in mud, sinkholes or tar, such as at La Brea in California, dropped as lag deposits by streams and rivers (cf. Voorhies, 1969; Wilson, 1960; Wolff, 1973) or they result from the activities of predators or scavengers (Klein, 1975; Mellett, 1973), including people. The first two agents can be readily ruled out at Buck Creek Cave. It is neither a natural trap nor is there an active stream nearby which could have concentrated faunal remains or any evidence that moving water is responsible for the cave's geological deposits. The bones therefore must have been accumulated by animals.

That predators of some kind were at least in part responsible for the Buck Creek Cave fauna is clear from the characteristics of gnawing, fragmentation and surface etching seen on the bones of animals of moderate and large sizes. Predators of the study area include eagles, hawks, owls, people and several canids, felids and mustelids; the only scavenger known to concentrate bones is the woodrat (Finley, 1958). Table 59 lists the known species that might be responsible for bones at Buck Creek Cave and the form in which bones might be deposited. The genus Homo has already been ruled out as a significant agent and the list can be further reduced by considering the behavior of animals and the characteristics of the depositional site. Hawks and eagles do not commonly roost in caves, and although larger owls are known to do so, there is no suitable roost in this cave, with its steep walls and low ceiling. Although the burrowing owl may occasionally inhabit

Table 59. Species Which Might Be Responsible for Bones in Buck Creek Cave

Latin name	Common name	Form of deposition
<u>Homo sapiens</u>	people	waste scraps
<u>Felis concolor</u>	cougar	scats, scraps
<u>Lynx rufus</u>	bobcat	scats, scraps
<u>Canis latrans</u>	coyote	scats, scraps
<u>Vulpes fulva</u>	red fox	scats, scraps
<u>Taxidea taxus</u>	badger	scats
<u>Aquila chrysaetos</u>	golden eagle	scats, scraps
<u>Tyto alba</u>	barn owl	pellets
<u>Bubo virginianus</u>	great horned owl	pellets
<u>Asio otus</u>	long eared owl	pellets
<u>Speotyto cunicularia</u>	burrowing owl	pellets
<u>Accipitriinae</u> and <u>Buteoninae</u>	various hawks	scats, scraps
<u>Neotoma cinerea</u>	bushy tailed woodrat	scavenged bones, scats and owl pellets

crevices, holes made by badgers and other large burrowing animals are most often used, and nesting in a cave as large as Buck Creek is unlikely. Therefore, the most likely contributors to the assemblage are the woodrat and five large predators: mountain lion (Felis concolor), bobcat (Lynx rufus), coyote (Canis latrans), red fox (Vulpes fulva) and badger (Taxidea taxus). The list can be further reduced by considering the ecologies of the five predators (Table 60).

Table 60. Food and Denning Habits of Five Large Predators Potentially Responsible for the Bones in Buck Creek Cave

Species	Common name	Denning	Food preference
<u>Felis concolor</u> ¹	cougar	Fallen trees, caves	Ungulates, largely cervid; smaller amounts of porcupine, hare, rarely small rodents.
<u>Lynx rufus</u> ²	bobcat	Any appropriate opening, including deep caves.	Catholic - predominantly mammals with leporids and rodents most common, ungulates and predators eaten but not often; carnivorous birds, mainly tetraonidae; Variable with habitat.
<u>Canis latrans</u> ³	coyote	Burrows; crevices, hollow logs, etc. less often.	Catholic - predominantly mammals with leporids, rodents most common; ungulates, especially deer; predators including other coyotes; carrion birds are mainly tetraonidae. Variable with habitat.
<u>Vulpes fulva</u> ⁴	red fox	Self-dug burrows	Small rodents, leporids, birds, insects, vegetable foods. Rabbits and microtines predominate; some carrion in winter; mustelids and members of own species avoided as food. Feet and tails of larger prey discarded.
<u>Taxidea taxus</u> ⁵	badger	Self-dug burrows	Ground squirrels predominate, various mice secondary.

1. Guggisberg 1975; Hornocker 1970.
2. Bailey 1972; Guggisberg 1975; Jones and Smith 1979.
3. Andrews and Boggess 1978; Berg and Chesness 1978; Gier 1975; Henderson 1930; Johnson and Hansen 1979; Ogle 1971; Sperry 1941; Young and Jackson 1951.
4. Abler 1975.
5. Errington 1937.

Only the coyote, bobcat and lynx are known to use caves as dens. By comparing the food preferences against the structure of the faunal assemblage from the cave (Table 61), one more species can be ruled out as a major contributor to the assemblage. Although coyote and bobcat have dietary preferences corresponding closely with contents of the cave (predominance of leporids and rodents, with some ungulates and carnivores, usually consumed as carrion), if the cougar were responsible for a significant proportion of the deposit, we would expect a much higher ratio of ungulates to rodents and leporids.

Coyote and bobcat are the most likely predators. Both are catholic in their feeding habits, and characteristically conform their feeding to the availability of animals in their environment. As a result, they are likely to deposit bones of animals in their scats in proportion to their availability in the environment to a greater extent than any of the other predators listed.

Another certain contributor is Neotoma cinerea. Not only is the animal present in the cave today, but its fecal pellets are the basic constituent of the floor deposits. Its bones, usually whole and unetched, are the most abundant in all levels and gnaw marks made by a rodent its size are common on larger bones. Species of Neotoma habitually collect bones, generally of ungulates and medium sized mammals such as leporids and marmots, along with carnivore scats and owl pellets, keeping them in or around their nests as sources of minerals (Finley, 1958). Given the fact that the mineral content of mammal bone is relatively uniform, and lacking evidence of selectivity by woodrats for bones of specific genera, one might expect that this rodent would collect animals' remains from its environment in proportion to their availability in sizes which the animal is able to transport.

The three taxa most likely to have deposited the Buck Creek bone collection are therefore bobcat, coyote and woodrat. All three are generalized predators and/or scavengers which are likely to collect and deposit animals in proportion to, though not in

Table 61. Mammalian Taxa Identified From Deposits at Buck Creek Cave*

Level	Rodentia														
	<u>Marmota</u>	<u>Spermophilus</u>	<u>Tamiasciurus</u>	<u>Claucomys</u>	<u>Eutamias</u>	<u>Thomomys</u>	<u>Neotoma</u>	<u>Peromyscus</u>	<u>Microtus sp.</u>	<u>Microtus richardsoni</u>	<u>Lagurus</u>	<u>Microtus/Lagurus</u>	<u>Phenacomys</u>	<u>Perognathus</u>	<u>Zapus</u>
0-10	141	26	0	1	4	46	201	23	3		26	23	6	3	
10-20	170	102	6	1	9	129	297	45	14		45	39	6	6	
20-30	213	85	8	1	13	216	358	82	22		83	78	4	21	1
30-40	176	70	10	1	11	229	373	63	21		79	80	3	32	2
40-50	169	62	1		12	132	270	48	13		61	72	1	17	
50-60	164	60	5		6	156	300	50	11		60	55	9	19	3
60-70	119	50	1	1	7	100	213	52	10	1	59	31	4	12	1

Level	Artiodactyla						Carnivora								Total *
	<u>Ovis canadensis</u>	<u>Bos/bison</u>	<u>Oreamnos</u>	<u>Odocoileus</u>	<u>Cervus</u>	<u>Antilocapra</u>	<u>Mustela</u>	<u>Martes</u>	<u>Taxidea</u>	<u>Vulpes</u>	<u>Canis</u>	<u>Canidae indet.</u>	<u>Lynx</u>	<u>Nepitius</u>	
0-10	15	3		1		5	1	2	1						531
10-20	33	5	1			1	6	1		3			1	1	921
20-30	21	5				1	5	2		3	1	2			1225
30-40	12	1				3	6			1	3	1			1178
40-50	13				1	5	7		1	5			1		891
50-60	4					1	6	2	1		3		1		917
60-70	10					5	7	3		2			1		689

*Values are numbers of identified specimens per arbitrary 10 cm level.

numerical equivalence to, their relative accessibility in the environment. This is especially true if, as is the case here, animals of similar size and anatomical structure are under consideration. Even if, for example, sheep was preferred over pronghorn as a food or mineral source, when the numbers of pronghorn are high relative to sheep these generalized predator-scavengers are likely to be depositing proportionately more bones of pronghorn than when the reverse is true.

Whether the relative contribution of these agents has remained constant cannot be demonstrated, but since all three are catholic in their food/bone collection habits and the approximate structure of the faunal assemblage from Buck Creek Cave has varied little in 2300 years, (Table 61, Figure 42) (see Results), this problem will have minor consequences.

Another factor that may be important though, is the environment into which bones were deposited. Regardless of the depositional mechanisms involved, the composition of any stratified series of paleontological samples may vary as a result of patterns of differential weathering, sorting or scat deposition. Caves contain a complex set of microenvironments, each with its own fauna and climate. Near the mouth is the drip line, an area that is more open to weathering by frost action, and to heat- and water-accelerated decay. Deeper in the cave, water may drip from the roof from time to time into some portions of the sediment surface while others remain totally dry. Predators of varying sizes and other cave inhabitants also seek out denning or bedding areas appropriate to their needs; woodrats are most common on ledges and deep crevices in walls or roof; larger carnivores can only inhabit larger spaces. Because of these environmental differences, the kinds of faunal remains and other debris collecting and being preserved on any one point on the sediment surface may differ from all other points, and they from each other. Should the form of the cave change with time, for example, a berm grow and make the site more or less attractive to predators or the ceiling become higher

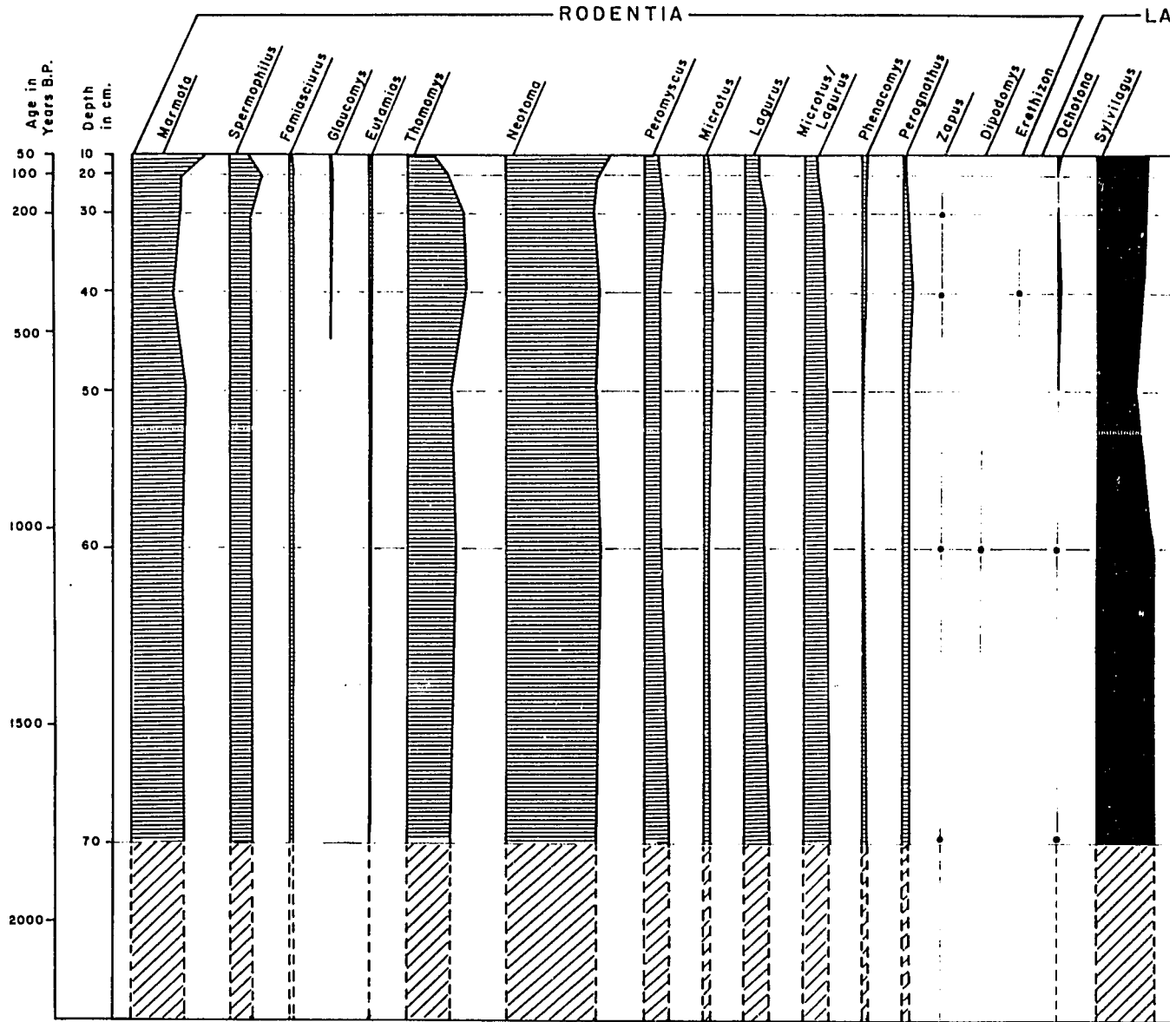
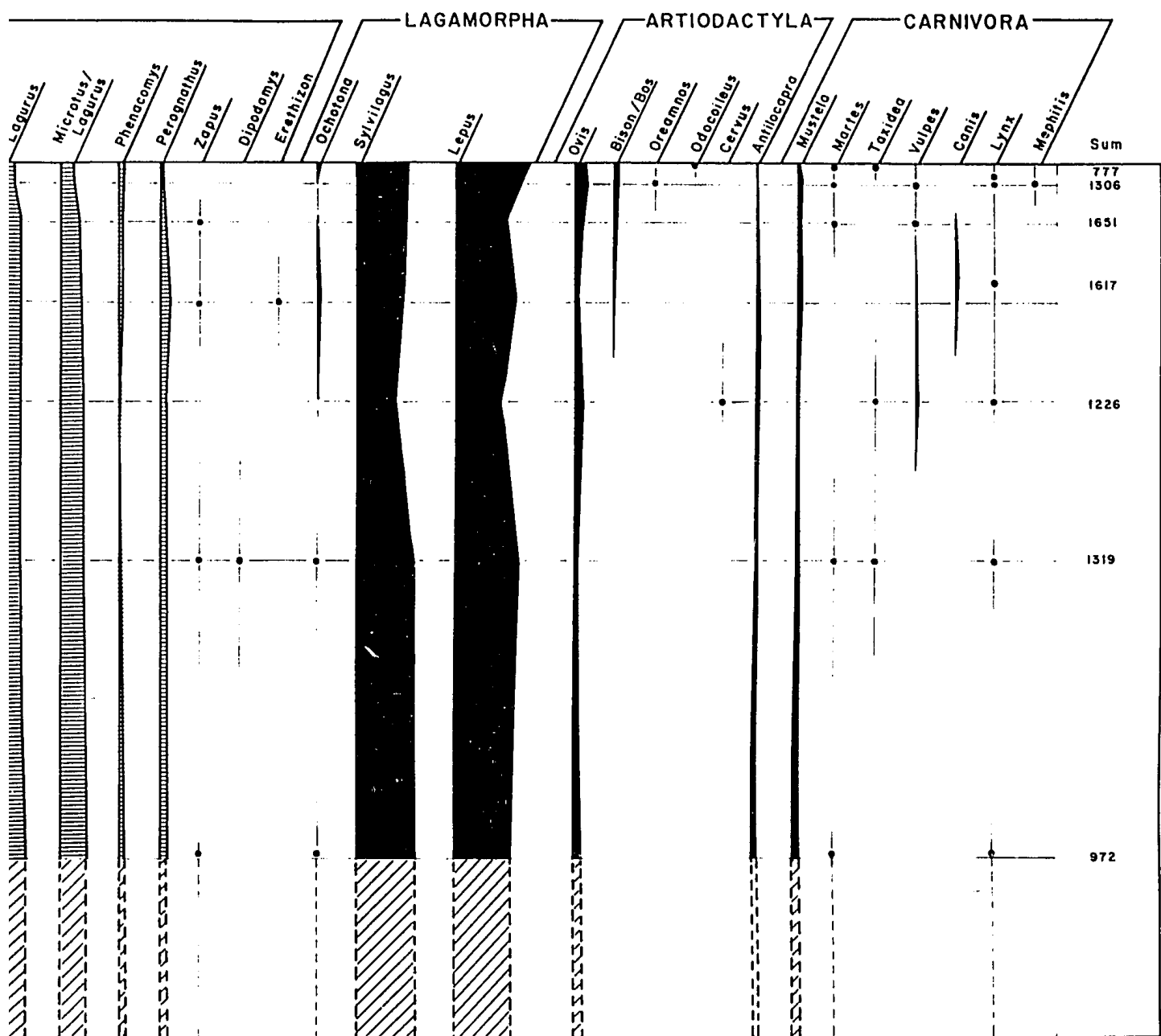


Figure 42. A percentage profile of the Buck Creek Cave fauna, based on the number of identified specimens.



ek Cave fauna,

or lower relative to the floor, the debris deposited at that same point on the surface may also change. If a paleontologist subsequently removes a stratified sample from point A, he may obtain two distinct bone populations and, if environmental variables are not taken into consideration, may draw spurious conclusions. Therefore, if we are to interpret changes in the ungulate fauna of Buck Creek Cave, it is necessary to determine whether the environment surrounding the sample location is likely to have changed enough to have affected patterns of bone deposition.

The sample came from an area near the cave mouth adjacent to the southwest wall (Figure 39), and there is no evidence to suggest a change in this relationship during the last 2300 years. This conclusion is based on the absence of a berm, the general paucity of roof-fall in Unit I and compaction of the sediments. The first two lines of evidence can be used to argue that the cave ceiling has not risen rapidly in recent millennia and that the mouth of the cave has not moved closer to the sample site as a result of extensive frost ablation at the cliff face. In fact, the evidence suggests that the cave mouth has receded little since Buck Creek actively eroded this wall of its canyon, probably not since the end of the Pinedale (cf. Funk, 1976). The importance of sediment compaction is that, in the absence of such compaction and without much rock falling from the cave roof, the cave floor would have risen rapidly (about 10 cm per 100 years), quickly filled the cave, and altered the depositional environment radically. With compaction, although new material is constantly being added to the floor, the rise is much slower (less than 10 cm per 1000 years in this case, a pace close to the rate at which the ceiling rose). Consequently, since cave roof, floor and mouth have maintained their relative positions for at least 2300 years, it is reasonable to suggest that the depositional environment of the sample site has remained approximately constant.

Independence of skeletal elements. When using NISP as the preferable measure of abundance when taxa are treated as attributes, it is necessary to demonstrate that each element in a collection was contributed by a different individual. In the case of vertebrates, this is impossible, short of first modelling the metric relationships among all bones in the skeleton of each taxon, then comparing each fossil element against the model to determine independence or interdependence between each pair of bones (a sophisticated way to determine MNI, cf. Casteel, 1975, 1976). This sort of exercise was not feasible for Buck Creek Cave, prevented by the time necessary to its execution, the fragmentary nature of most bones in the collection, and by the fact that too few skeletons of each species were available in local and regional collections to provide a model with statistical validity. In lieu of this costly procedure I shall increase the plausibility of an assumption of independence by considering three factors: (1) the probable mechanism by which bones reached the site, (2) the age distribution of ungulate elements as a means for arguing that many animals contributed to each small assemblage of ungulate bones, and (3) a comparison of several fragments representing the same element from one species to determine whether each came from a different individual.

The Buck Creek Cave assemblage is a coprocoenesis (Mellest, 1974), deposited primarily by coyote and bobcat, with an additional component contributed by bone scavenging woodrats. Most specimens are small, and etched fragments or individual heavily gnawed bones, usually from ungulate feet. Most fragments, therefore, probably entered the cave as independent units. It is difficult to conceive of a coyote or bobcat expelling in a single fecal mass more than one or a very few fragments of ungulate bone large enough to still be identifiable. For their part, woodrats collect isolated bones or, at most, sets of small, articulated bones such as portions of a mandible or foot.

Additional support for the idea that most specimens are independent comes from the age distribution of elements in all levels (Table 62) and the sizes of trochlea from sheep metacarpals, found in the 10 - 20 cm level (Figure 43). Age distribution is measured by tooth wear and the degree of epiphyseal union in long bones and feet. Table 62 shows these data for only bighorn sheep and pronghorn; there were no cow/bison teeth and all foot bones came from mature individuals, with no more than one specimen per level with an intact epiphysis. It is evident in nearly every case that, even though the numbers of specimens are small, two and usually three age classes and, hence, different individuals are represented. The analysis can be carried further, using the MNI method of White (1953) to show that among the teeth in various age classes, there also are separate individuals. In the 10 - 20 cm level, for example, the five heavily worn teeth include two upper left first molars and three upper left third premolars, thus raising the number of individuals represented by teeth to six. More than one individual is also responsible for the five normally worn adult teeth in 0 - 10, and the four heavily worn sheep teeth in each of 30 - 40 and 60 - 70.

Carrying this same argument to epiphyseal union, it can be shown that, in one case at least, all the specimens of one element came from separate individuals. Only in the 10 - 20 cm level are there enough specimens from the portion of the same skeletal element of one taxon for this mode of analysis to be used. The element is the metacarpal; species, bighorn sheep; the portion, distal trochlea. There are four specimens, all with fused epiphyses. For this analysis, I first ascertained where two measurements could be taken on the articular surface of all the fossil specimens. These were the maximum medial-lateral width of the articular surface taken at the extreme distal end of the bone (Figure 43, A-A') and the minimum anterior-posterior width of the outer trochlear surface taken perpendicular with the bone's long axis (Figure 43, B-B'). I then took these measurements from all

Table 62. Age Distribution of Ungulate Elements*

Teeth, wear class	Depth in cm						Total
	0-10	10-20	20-30	30-40	40-50	50-60	60-70
deciduous unworn or in normal wear			1	2	2		5
erupted, unworn or heavily worn deciduous		1			1		2
erupted, normal wear	5	1	2				8
erupted, extreme wear, little enamel remaining		5	2	4(2)	2	(1)	4
Total	5	7	5	6(2)	5	(1)	4
Epiphyseal union							
unfused	1	3		0	1(1)	1	1(1)
fused	7(3)	12(1)		7(1)	4(3)	2	1
Total	8(3)	15(1)		7(1)	5(4)	3	2(1)

*Wear classes of teeth and epiphyseal union are considered in separate portions of this table. Numbers represent bighorn sheep (Ovis canadensis) and pronghorn (Antilocapra) (in parentheses).

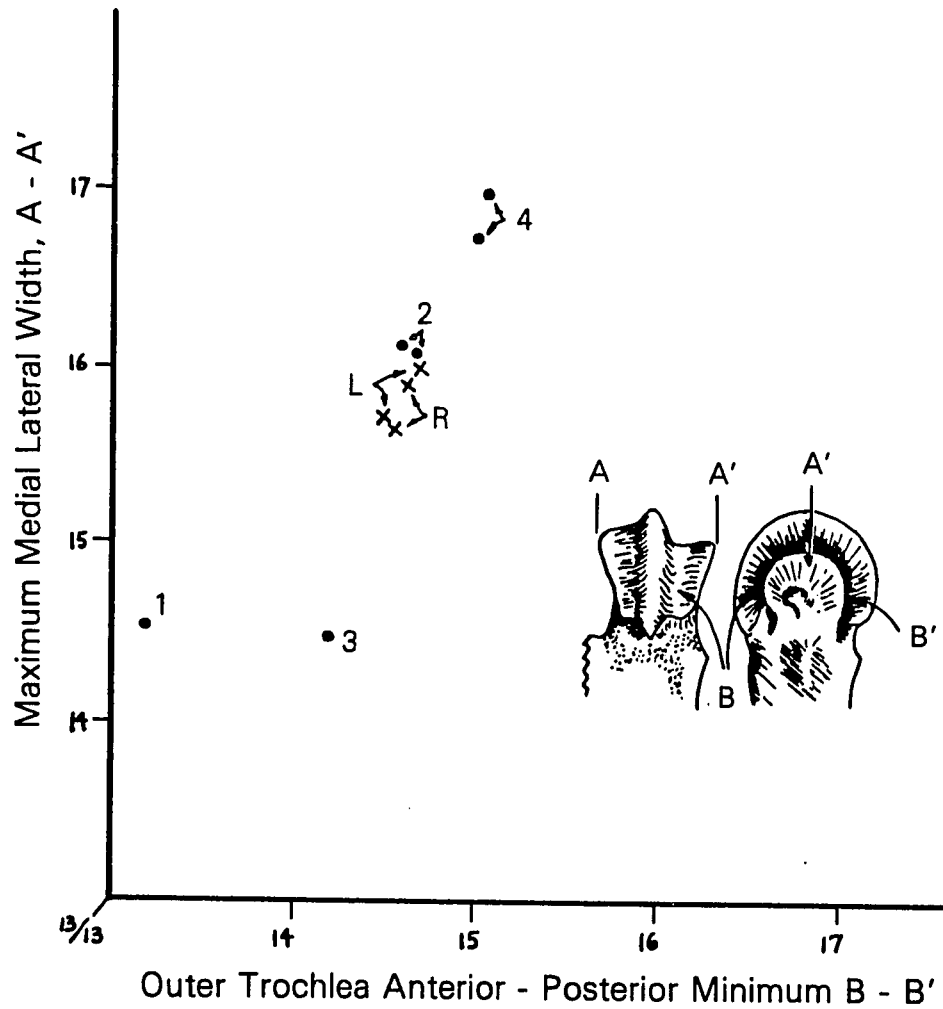


Figure 43. Metric characteristics of trochlea from mountain sheep metacarpals, comparing fossil specimens from the 10-20cm level of Buck Creek Cave (numbered dots) with a modern example (x). Where a specimen included both trochlea, each is shown. Drawing indicates the points of measurement.

four metacarpal trochlea of the single comparative specimen of Ovis canadensis available to me (my own, adult female) and plotted these on a two pole graph. The points, as expected, cluster tightly together, with the inner trochlea slightly smaller than the outer. Assuming from this distribution that all trochlea from the metacarpals of a sheep would always display such a high degree of clustering, I then compared measurements of the four fossil specimens (Figure 43). As the figure shows, all are distinct in size and must certainly come from separate animals. A fifth metacarpal in the same collection is from a juvenile, so that each specimen represents an individual.

The three arguments I have just presented do indicate that the assumption of element independence has some value here, but they are still equivocal. I could likewise continue with analyses of this kind, showing, for example, that specimens of a single taxon, cow/bison in 10 - 20 cm, for example, show different degrees of mechanical and chemical weathering (etching, exfoliation and the absence of either). The probability of my assumption would increase slightly each time, but there would never be sufficient data to argue that every specimen is from a different individual; some probably are not. Nevertheless, because of the anatomical similarity of the taxa of interest and the presumably constant contribution of the depositional mechanisms, deviation from element independence, which in any case is rare, should be a random phenomenon and consistent trends in relative taxonomic abundances of species are unlikely to have been caused by element interdependence alone.

Summary. Based on a review of the paleontological data from Buck Creek Cave, I conclude that the mechanisms contributing to this bone accumulation were bobcats, coyotes and woodrats; that the relative contribution of each has remained approximately constant and that because of these depositional agents, the assemblage can be treated as a set of independent skeletal elements. I therefore

treat taxa as variables in the analysis of the Buck Creek paleofauna, recognizing the limitations of this approach, but having minimized those limitations to the greatest extent feasible.

Interpretation of the Surface Fauna

Behrensmeyer and her associates (Behrensmeyer, 1978; Behrensmeyer et al., 1979) have shown that skeletal remains found on the ground surface in a region do not accurately reflect living populations of mammals either in the species represented or in the numerical relationships among species. In their study of skeletal remains found on the Amboseli National Park in Kenya, Behrensmeyer, Western and Dichant-Boaz found that only 74 percent of the known taxa were represented and that the relative abundances among species differed from modern census data. These biases were strongly correlated with body size, resulting from a more rapid destruction of smaller skeletons by carnivores, trampling and chemical weathering (Behrensmeyer, 1978).

Clearly, a simple equation of numbers of animal bones found on the surface with the living ungulate populations from which they came would be invalid. Pronghorn, deer and both species of sheep would be under-represented, especially among the older, Class 3 remains, while proportions of cattle, horses and bison would tend to be over-represented.

In working with surface fauna, neither the taxa as variables nor the taxa as attributes approach is entirely appropriate to answer the questions I am concerned with here. Taxa, especially smaller animals, that are actually present in the ecosystem may be absent from surface collections and may also be numerically under-represented, especially in older weathering classes, because of their size. The problem is probably not so great in the Pahasimeroi Valley, where the largest carnivore, the coyote, is as capable of destroying cow bones as those of pronghorn, as it is in Africa, where animal sizes are more divergent and carrion eaters (eg.,

hyaenas) are more effective consumers of bones from animals to cow size and larger, it will still compromise the results of my analysis.

In considering presence and absence, the size bias is to be treated as follows. Because large mammals tend to be better preserved than small ones, their absence in the collection will be interpreted as either absence or rarity in the living community, regardless of the time period. Smaller animals, especially pronghorn and domestic sheep can be expected to occur in Class 1 or 2, if present in the area, but their absence from Class 3 is as likely to result from poor preservation as from absence or a low population. Taking this further, if small taxa are represented in Class 3, but absent from Class 1, we may conclude that their numbers have declined.

No such simple solution exists for relative abundance. I am especially interested in the proportion of pronghorn to cattle. Their weights differ by a factor of ten or more, which on the face of it makes them seem so disparate in size that differential bone survival should be a significant problem. However, the bones of cattle are less than twice the size of the pronghorn's and the difference in bone thickness is even less than that. Consequently, although it will have some impact, and leaves the results open to some question, differential bone survival should not be responsible for marked changes in the relative abundances of these taxa.

Results

The Cave

The Buck Creek Cave assemblage included 30 taxa of mammals (Chatters, 1980b). Except for the kangaroo rat (Dipodomys), lemming (Dicrostonyx) and bison, all genera can still be found in the Project Area (Hall and Kelson, 1959). Data for the uppermost 70 cm of the deposit, representing the period for which archaeological

data on the human niche were available, are summarized in Table 61 and Figure 42.

For the most part, the taxonomic structure has remained fairly constant for the entire 2300 year period. Marmot (Marmota), jack-rabbit (Lepus), cottontail (Sylvilagus), pocket gopher (Thomomys) and woodrat (Neotoma) are always the most abundant, with ground squirrels (Spermophilus), deer mouse (Peromyscus) and sage vole (Lagurus curtatus) consistently among the top ten. Ungulates and carnivores are never numerous, with mountain sheep (Ovis canadensis) and Mustela (weasel, mink) the best represented.

Ungulates. Pronghorn and mountain sheep are present in all levels, but bison/cow appear only above 40 cm (Table 63). All other taxa are limited to one specimen each. Deer, which appears only in the 0 - 10 cm unit, was also present in surface collections, both in the cave and elsewhere in the study area (see Table 64). Its general absence in the cave deposit is difficult to reconcile, given the presence of good deer habitat in Buck Creek Canyon, unless the species had been absent or rare in the catchment area of the animals depositing bones to the site. Deer, it seems, expanded their range into this region at the same time various domesticates were introduced, within the last 90 years, and are a part of a different ecosystem created by people of the Metallic Tradition. Changing percentages among the four taxa which represent the effective environment of people are presented graphically (Figure 44, see also Table 61). Ignoring the 50 - 60 cm level as too strongly affected by a small sample size, it is evident that the proportion of pronghorn to mountain sheep was relatively high before 460 BP, compared to the subsequent 400 year period. After 65 BP, pronghorn shows a sharp increase and deer appear.

Cow/Bison (certainly bison in the earlier years) is rare before 500 BP, although its archaeological presence during the same period shows that this taxon was at least present. Cow/Bison increases to a maximum between 260 and 125 BP. The lack of a

Table 63. The Ungulate Fauna of Buck Creek Cave*

Taxon	Common Name	0-10	10-20	20-30	30-40	40-50	50-60	60-70
<u>Ovis canadensis</u>		15	33	21	12	13	4	10
	mountain sheep	(.65)	(.84)	(.78)	(.75)	(.72)	(.80)	(.67)
<u>Bos/bison</u>		3	5	5	1	—	—	—
	cow/bison	(.12)	(.13)	(.18)	(.06)			
<u>Oreamnos</u>		—	1	—	—	—	—	—
	mountain goat							
<u>Odocoileus</u> spp.		1	—	—	—	—	—	—
	deer	(.05)						
<u>Cervus</u>		—	—	—	—	1	—	—
	elk							
<u>Antilocapra</u>		5	1	1	3	5	1	5
	pronghorn	(.21)	(.03)	(.04)	(.11)	(.28)	(.20)	(.33)
Total		23	40	27	16	19	5	15
Total minus <u>Oreamnos</u> and <u>Cervus</u>		23	39	27	16	18	5	15

*Included in the table below are NISP figures for all ungulate taxa plus the percentages in parentheses of mountain sheep, pronghorn, cow/bison and deer of the total of these four taxa.

Table 64. Ungulates Observed on the Surface in the Project Area*

Taxon	Common Name	1 +25 to +20	2 20 to +20	3 pre- 20 BP	Total
<u>Antilocapra</u>					
	pronghorn	5	7	3	15
<u>Odocoileus</u> spp.					
	deer	1	2	1	4
<u>Ovis canadensis</u>					
	bighorn sheep			+	+
<u>Bos/bison</u>					
	cow/bison			2	2
<u>Bos</u>					
	cow	3	2	1	6
<u>Equus</u>					
	horse			4	4
<u>Ovis aries</u>					
	domestic sheep			2	2
Total		9	11	13	33

*Presented by weathering class (age). Figures represent the number of bone clusters (skeletons or isolated bones) observed on survey transects. The plus sign (+) denotes taxa observed only outside survey transects. Animals in the Bos/bison group are probably all Bos.

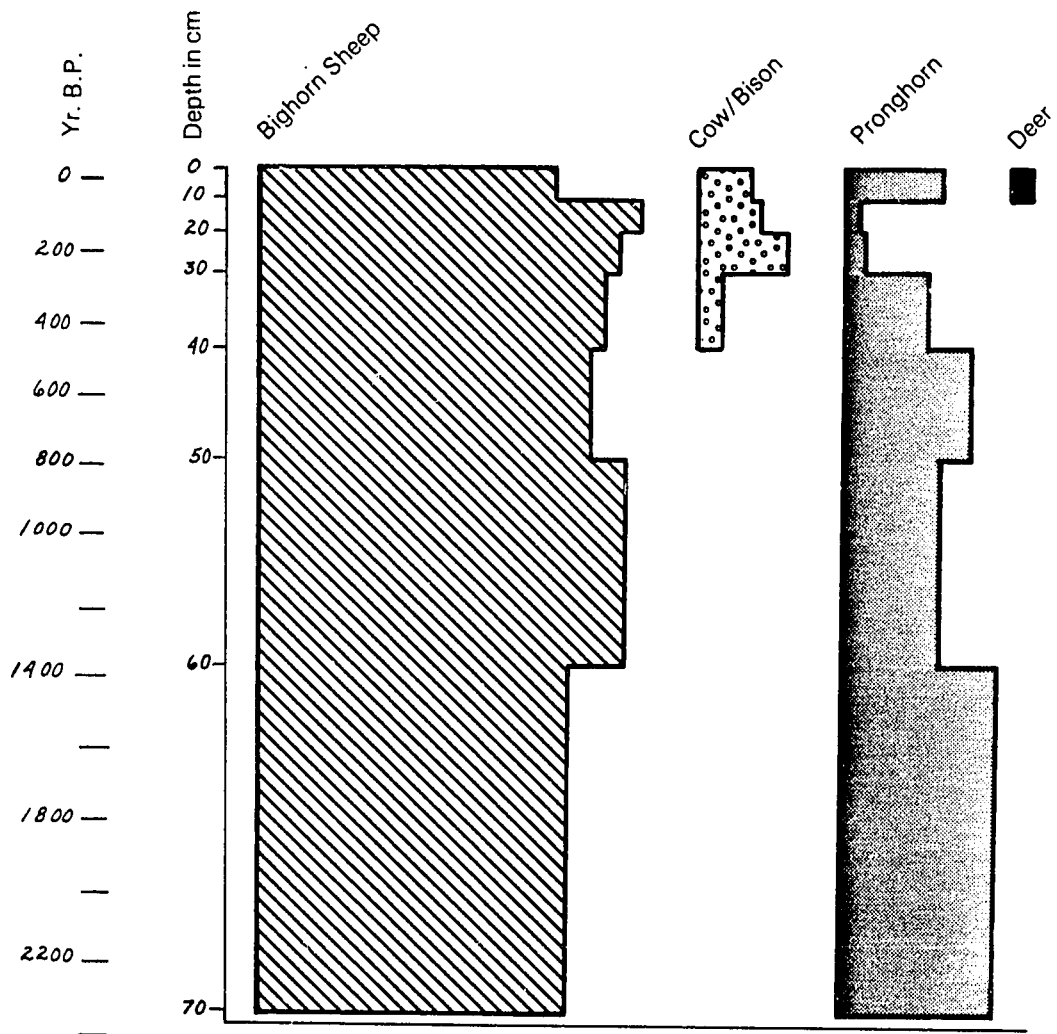


Figure 44. Profile of ungulate percentages from the uppermost 70cm at Buck Creek Cave. Only the taxa that make up the effective environment of human populations are included. Sample sizes are listed in Table 63.

decline in this taxon during the modern period (0 - 10 cm), even though bison are known to have been locally extinct by early Metallic Tradition times (Butler, 1971b), is due to my inability to distinguish Bos from Bison. The most recent elements in this group are probably from cattle. There do appear to have been changes in the proportions of bison to pronghorn and sheep in the vicinity of Buck Creek Cave, but before my conclusions can be drawn with regard to the hypotheses I posed in the introduction to this chapter, one final question must be resolved. The samples of all ungulate taxa are low and conceivably the proportions, especially of the least common in each group, could be a function of sample size alone. There is a tendency for least abundant genera to vary inversely with sample size as a result of sampling error (Grayson, 1981b). Spearman's Rank Order correlations were calculated to test for this phenomenon comparing total size for each ungulate sample (Table 63) with the abundances of bighorn sheep (1.00), pronghorn (-0.32) and cow/bison (0.3; 4 pairs only). since sheep is so numerically superior, its precise correlation with sample size is not surprising. None of the correlations is significantly negative, so the observed changes in the proportions of these animals are unlikely to be the result of sampling error.

Surface Fauna

Table 64 presents data on skeletal elements from the surface of survey transects, supplemented by observations made elsewhere in the Project Area. Note that, since 20 BP the number of genera has declined from six to three. Sometime before 20 BP a fauna including mountain sheep, pronghorn, deer, cattle, horses and domestic sheep became less varied and now only cattle, pronghorn and deer are common. Although differential preservation may be partially responsible, there is an apparent increase in the relative importance of wild ungulates, mostly pronghorn, relative to domesticates, now only cattle, after 20 BP.

Before 20 BP, the ratio of pronghorn and deer to domesticates is 1:2.25. In the next 40 year period, during which the change in resource niche and adaptive pattern occurs in the Metallic Tradition, the ratio is 4.5:1. Thereafter, the number declines to 2:1. These differences may be partially due to factors of bone survival, but a comparison with data from the 0 - 10 cm level of Buck Creek Cave, deposited during the last 90 years, in which the ratio of pronghorn and deer to cattle also shows a distinct rise from 10 - 20 cm levels (Figure 44), supports the conclusion that the relative numbers of wild and domestic ungulates actually changed. The increase in wild taxa is manifest principally in the relative abundance of pronghorn, the proportion of deer in the faunal assemblage remaining approximately stable. Therefore, I consider only pronghorn at this juncture in further discussions.

Summary: Testing the Hypotheses

If changes in the patterns of adaptation followed by human inhabitants of the Pahsimeroi Valley were caused by climatic events, we should observe changes in the people's effective environments coinciding with or preceding changes in the resource niche. For the change between Periods 5 and 6, occurring around 400 BP, this means we should see an increase in bison relative to mountain sheep and pronghorn. Disappearance of the horse and domestic sheep, coincident with a sharp rise in the ratio of pronghorn to cattle, is expected between Periods 8 and 9, before +2 BP. If these changes do not occur, some cultural phenomenon has provided selective pressure for the change.

Faunal remains from Buck Creek Cave, a small cavern in the Project Area, and from the surface of survey transects, although small in number, support the effective environment hypothesis in both instances. In Buck Creek Cave, bison increases relative to pronghorn and bighorn sheep after 460 BP, preceding the observed cultural change of ca. 400 BP. The cave fauna also shows a rise in the proportion of wild to domestic ungulates after 65 BP, and

surface fauna clarify the timing of this event: around 20 BP. Cattle decline relative to pronghorn while horse and domestic sheep effectively disappear. These changes have been completed some 20 years before there is a major reorganization of the Metallic Tradition adaptive pattern and resource niche.

CHAPTER TEN

Pahsimeroi Valley Steppes of the Last 2700 Years

Human activity in the Upper Pahsimeroi Valley during the past 2500 years has been oriented toward the exploitation of wild and domestic ungulates. Changes in the local presence and proportional abundance of each of seven taxa have been demonstrated and some of these changes are coincident with patterns of land use and ungulate exploitation. Specifically, between Periods 5 and 6 an increase in the proportion of bison occasions increased exploitation of this species and a shift in hunting patterns and the sizes of domestic settlements. From Period 8 to Period 9 domesticates; horse, cow and sheep are replaced by a fauna in which pronghorn are dominant and cattle secondary. This habitat change results in a shift from a pastoral adaptation with permanent settlements to one emphasizing seasonal hunting of wild ungulates, primarily the pronghorn, from temporary camps. Enroute to determining whether climatic change precipitated change in cultural adaptations or some other cause must be invoked, we must first determine the cause of variation in ungulate populations. Three hypotheses can be advanced to account for such variation which for simplicity I will call genetic, ecological and cultural.

The genetic hypothesis states that observed changes in the ungulate fauna result from evolution of the organisms themselves, altering the competitive relationships between species. This hypothesis can be rejected immediately. During the brief period with which we are concerned there have been no changes in the morphology of wild North American ungulates that are sufficient to have caused marked changes in their ecologies. Domestic fauna, which have long been subject to selective breeding, have undergone extensive genetic modification in the last 10,000 years. However, in the less than 100 years during which they have been present in the Pahsimeroi

Valley, sheep and horses are unlikely to have changed enough to alter their competitive status relative to each other and to wild ungulates.

Cattle have undergone some changes since 100 BP, but this too has probably had little effect on their ecology. During the 1870's and 1880's, cattle ranges of the northwestern Great Plains were populated with longhorn cattle driven up from Texas (Rouse, 1973). Small and rangy, the longhorns were hardy animals but had a low meat-bone ratio, and cattlemen quickly began to upgrade their herds by replacing longhorn bulls with first shorthorn, then herefords (cf. Oliphant, 1968; Rouse, 1973; Von Richthofen, 1885). This transformation was well underway by 1880 and by 1900 when the first building and corral complexes (settlement type MS3) began to appear in the Project Area, along with cattle, horses and sheep, the common white-face cow of the western ranges had been produced. The cross is well-known for its hardiness and fertility, which approximates that of the longhorn ancestor (Rouse, 1973). It is still the dominant breed in the Project Area, so the shift in the competitive relationship between this species and the pronghorn does not result from biological change during the past century.

The ecological hypothesis is based on the niches of the various taxa and invokes a change in the effective environment of one or another species, specifically the plants used for forage. Except for mule deer, which is never an important member of the local fauna, all ungulates used by people of the Pahsimeroi Valley have either sagebrush or grass as the primary component of their diet (Table 65). Bison, cow, horse, and both species of sheep are principally grazers, preferentially consuming grasses and forbs. Pronghorn, by contrast, is a browser that feeds almost exclusively on sagebrush. If a change in the effective environment is the cause of change in proportional abundances of species, we would expect to see a sudden increase in the proportion of grass in the local steppe flora around 400 - 500 years ago and a similar rise in sagebrush

Table 65. Food habits of Ungulates*

Species	Summary of Food Habits	References
<u>Antilocapra americana</u>	Feeds almost exclusively on shrubs, predominantly sagebrush, in all seasons. Some forbs are eaten in spring; grass almost never.	Einarson 1947; Grimm 1939; Olsen and Hansen 1977; Van Wormer 1968.
<u>Bison bison</u>	Eats grass in all seasons to the near exclusion of other plants. Estimates range from 80-99% grass, under 1% shrubs, the rest are forbs.	Martin et al 1951; Meagler 1973; Peden et al 1974.
<u>Bos taurus</u>	Grass is the preferred forage. In lightly grazed pastures, from 70-90% of food is grass; 35-97% in heavily grazed locations. Forbs (light to 27%, heavy to 47%) and shrubs (light to 38%, heavy to 47%) make up varying proportions of the diet.	Hansen et al 1977; Hubbard and Hansen 1976; Peden et al 1974; Olsen and Hansen 1977; Vavra 1977.
<u>Equus caballus</u>	Much like cattle in food preferences, feed on around 80% grasses; up to 17% shrubs. Preferred shrub is serviceberry.	Hansen et al 1977; Hubbard and Hansen 1976; Olsen and Hansen 1977.
<u>Ovis aries</u>	Grass makes up 40-89% of diet, is identified as the principal food. In late winter and early spring, respectively, shrubs and forbs predominate. <u>Atriplex</u> is the preferred shrub.	Peden et al 1974; Olsen and Hansen 1977.
<u>Ovis canadensis</u>	Reports vary, but most identify grass as the principal food, 63-94% of the diet. Shrubs, a winter food, are secondary, consisting mainly of pasture sage (<u>A. frigida</u>) and mountain mahogany (<u>Cercocarpus edifolius</u>).	Blood 1967; Covey 1950; Cowan 1947; Mills 1937; McCann 1956; Smith 1954.

*Derived from studies of feeding time, stomach contents, cropped stems and fecal pellets.

at the expense of grasses in the 100 year period encompassed by the Metallic Tradition.

If these expectations are not met, the remaining hypothesis, that cultural activity caused change in animal populations, is the most probable. As an artifact, the cultural cause is only acceptable if no non-cultural explanation is sufficient to account for the observed event.

The floral history of the project area was studied through the analysis of a pollen core from a large pond in the upper sagebrush-bunchgrass steppe zone. This chapter presents the results of that analysis as a test of the hypothesis that changes in the proportion of grass to sagebrush caused fluctuations in the composition of the local fauna.

Bisonsweh Pond

On the east side of Spring Hill, a large isolated mountain mass in the Project Area, there is evidence of a massive land slide that scattered clays and igneous rock over a fan-shaped area 3 km long and 1.5 km wide. The undulating surface of this great slide contains many basins of various size; most of them accentuated by the lush grasses and sedges that flourish in the moisture captured and retained by the clay substrate. A few of the larger basins are filled with water from a small, spring-fed stream that flows from near the apex of the slide, and are surrounded by a lush growth of riparian vegetation (Figure 45). The largest of these ponds was chosen for palynological studies. I have named the pond Bisonsweh after the many bison bones found protruding from the mud of its shallow end (Chatters, 1977).

Bisonsweh Pond is an elliptical body of water approximately 120 m east-west by 40 m north-south, with an area of approximately one hectare. It lies at 2220 m a.s.l., situated where the landslide, confined to a narrow canyon, expands out onto the alluvial plain of the Pahsimeroi River. The tiny (1 to 2 m wide) feeder stream enters at the pond's west end, and exits over a natural earth

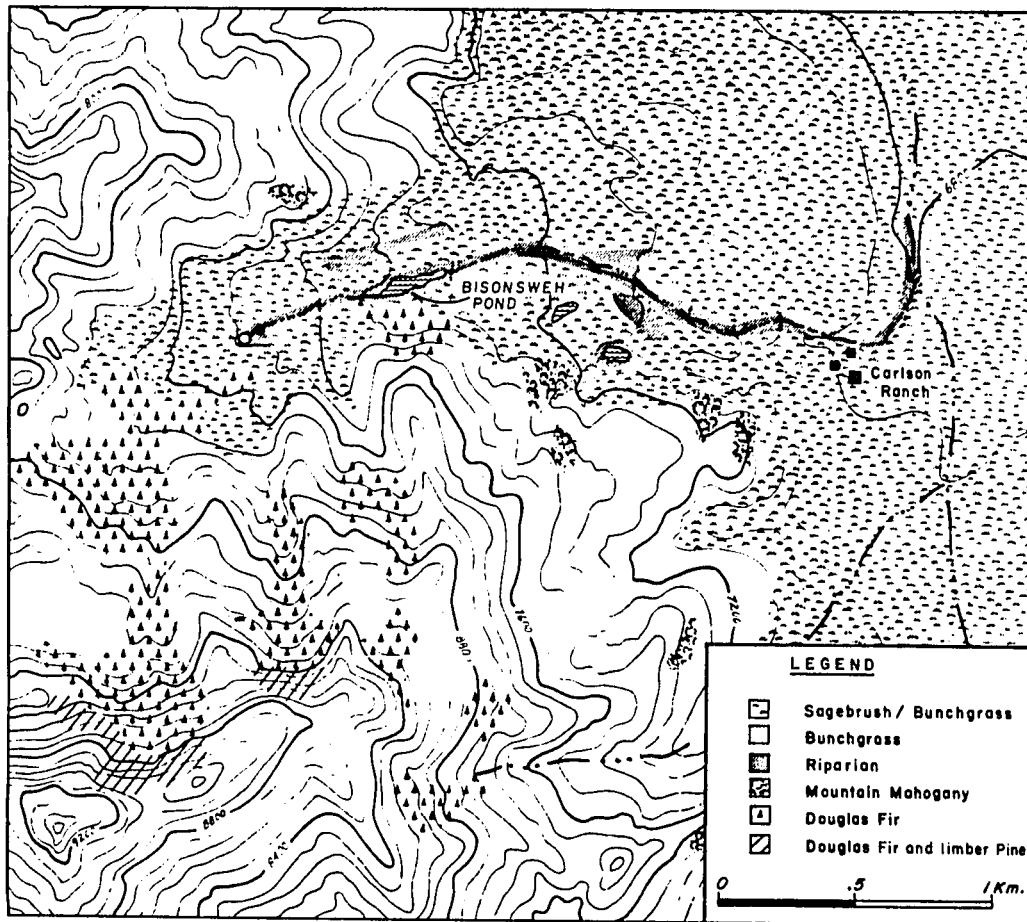


Figure 45. Topography and flora of the Bisonsweh Pond vicinity.

dam that forms the pond's eastern boundary. The stream then continues down the slide past site 10CR526, and the Carlson Ranch. Then, after a short distance it sinks into alluvial gravels of the open plain.

The pond fills a trough-like depression, with a level, shallow area at the east end, and a deep, elongated center and west end. Banks slope gently to the sediment surface in shallow portions of the pond, but drop steeply off into the deeper center. Water depth at the time of coring (September 4, 1975) was 170 cm in the geographic center, and averaged 50 cm in the shallow east and west ends.

Vegetation on the pond's east, west and south shores is riparian, comprised of willow (Salix spp.), cottonwood (Populus trichocarpa), rose (Rosa woodsii) and currant (Ribes spp.) with an understory of sedges, grasses and forbs. These thickets are most extensive at the west end of the pond, but form only a narrow band elsewhere. On the north bank, patches of riparian flora are separated by a steppe of big sagebrush (Artemisia tridentata) and blue-bunch wheatgrass (Agropyron spicatum) which reaches nearly to the water's edge in some areas.

Scattered Douglas fir (Pseudotsuga menziesii glauca) grow on the south side of the pond, among the cottonwoods and a dense grove occurs on a nearby north-facing hill slope. Additional patches of Douglas fir forest grow on scattered, well protected sites at higher elevations in the slide basin. A few stands of Limber pine (P. flexilis) are also found there, interspersed among the Douglas fir near the upper treeline.

Beside the few, sparse patches of mountain mahogany (Cercocarpus ledifolius) that cling to rocky hillsides, the remaining land surface within 5 km of the pond supports various forms of steppe. The landslide, open alluvial plain and lower hill slopes are covered by sagebrush and bunchgrass; grasses dominate at higher elevations. In fact, fully 90 percent of the flora near Bisonsweh Pond is some kind of steppe.

Situated as it is within the steppes, Bisonsweh Pond was considered an ideal site from which to acquire a palynological history of sagebrush and bunchgrass in the Project Area.

Technique

To obtain a sediment core for analysis, a plywood and styrofoam raft was first anchored in the geographic center of the lake, in the deep end. Two cores were then extracted using a 5 cm diameter Livingstone piston sampler in the manner described by Deevey (1965). The first core (#1) was pushed to a depth of 464 cm, where compact, silty sediment prevented further penetration. A second core (#2), taken 3 m to the west of the first as an auxiliary sample of near-surface sediments, was only 41 cm long.

Cores were removed in 1 m sections. Segments of aluminum alloy tubing were filled with sediment, removed from the coring assembly and sealed with rubber stoppers and tape to prevent drying and aerobic decay. Tubes were then transported to the laboratory and kept cool until the cores could be described and sampled.

Sections of Core 1 were extruded with a piston-like apparatus, split lengthwise, and photographed in color. Lithology was described with the aid of a Munsel Color Chart and two sets of samples were taken, one at 5 cm intervals for pollen analysis, a second at 10 cm intervals for measurements of organic carbon and dry weight. Each sample had a volume of 0.6 cubic cm, measured by packing sediment into a calibrated measuring spoon. Also at this time, 10 cm-long samples for radiocarbon assay were removed from one side of the split core, with sample midpoints at 92 cm, 195 cm, 312 cm, 412 cm and 442 cm. When it became evident that the time period of interest to this study was represented by only the uppermost 23 cm of the core (see Dating, below), Core 2 was sampled. This time, to avoid the compression of sediments that often had occurred in the extrusion process, the core was frozen and the aluminum tube split lengthwise from the solidified core. The core was then cleaned, described and sawed into 1 cm segments. Samples

were removed from thawed sediment for pollen and organic carbon analysis. Pollen was identified from this core only.

The weight loss on ignition method was used to determine organic carbon content. This procedure entailed weighing each dried sample, burning it at 600 C for two hours and then weighing it again. The resultant data were used to determine the ratio of organic to inorganic sediment in each sample for a measure of variations in the rate of sediment deposition.

Each pollen sample was treated by acetolysis to concentrate the fossil palynomorphs (Faegri and Iversen, 1975), following the technique outlined by Waddington (n.d.). Before the treatment began, one weighed tablet of Eucalyptus pollen was added to each sample as an exotic pollen of known concentration. Eucalyptus was then used as a constant in the calculation of pollen concentration rates by Maher's technique (1972).

With acetolysis completed, slides were prepared using silicone oil as the mounting medium and identifications made at 480x with a binocular Zeiss microscope. To avoid problems that might have resulted from size sorting of pollen under a cover slip, each entire slide was counted in transects 1 mm apart. If a minimum of 200 terrestrial grains (cf. Hills, 1969; Moore and Webb, 1978) was not found on the first slide, a second complete slide was counted, then another, until the minimum had been surpassed. In practice, pollen sums ranged from 222 to 595 grains. All samples from the uppermost 14 cm were counted, but below that only every other sample was used. Close spacing was maintained in the upper part of the core to ensure a detailed record from the period for which dendroclimatic information was available.

Identifications were made with the aid of keys (Kapp, 1969; McAndrews et al., 1973) and comparative specimens from the collection of Dr. E. B. Leopold of the University of Washington College of Forest Resources. Mr. Rudy Nickmann, assisted with some difficult cases. Cupressaceae, a problematic type that I could not consistently distinguish from algal cysts, was not counted.

Lithology

A simplified profile of the long sediment core is presented in Figure 46. The core begins at 464 cm with a thin layer of dense, silty sediment of a very dark brown color. That layer is followed by a highly decomposed peat layer, then a layer of nearly pure algal gyttja over 100 cm thick. At 317 cm, alternating laminations of gyttja and peat begin, extending to 236 cm. A layer of gyttja to 188 cm is overlaid by a thick peat stratum composed primarily of Elodea spp. this peat is covered by gyttja, then more Elodea peat and, finally, from 23 cm to the surface, a second layer of very dark brown, dense, silty sediment. The short, second core had an identical lithology, described in more detail in Table 66.

Table 66. Lithology of Bisonsweh Pond, Core No. 2

Layer	Depth	Color	Content
1	0-10.5cm	dark brown	silty organic sediment
2	10.5-17.5cm	lighter dark brown, darkest 10.5-15cm.	silty, organic sediment
3	17.5-23.5cm	very dark brown darkest 18-22cm	silty organic sediment
4	23.5-28.0cm	lighter dark brown	organic sediment, sand silt seeds of various aquatic present.
5	28.0-33.2cm	dark yellow-brown	fibrous peat/gyttja with an abundance of plant fragments, mostly <u>Elodea</u> .
6	33.2-41.0cm	dark yellow-brown	fibrous peat, a solid mass of plant fibers, mostly <u>Elodea</u> .

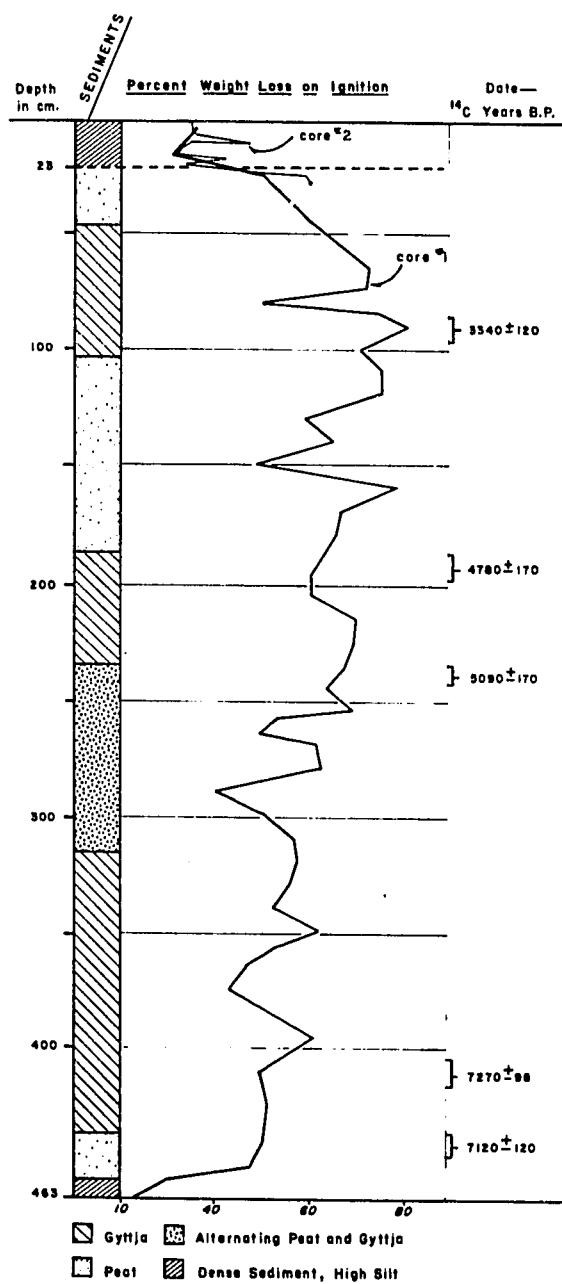


Figure 46. Lithology and weight-loss diagrams for cores 1 and 2 from Bisonsweh Pond.

Organic Carbon Content

Ignition of samples from both cores demonstrated that in most cases, the sediment of Bisonsweh Pond is largely organic (Figure 46). Between 23 and 450 cm, the weight-loss on ignition averaged between 40 percent near the base of the core and 55 percent near the surface. At either end of the core, however, organic content was much lower with average weight loss of 17 percent at the bottom and 24 percent in the top 23 cm.

Predictably, figures for weight loss on ignition correspond closely with core lithology. Layers of dense, silty sediment lost little weight, reflecting a low organic content in contrast with the high organic fraction in peats and gyttja. Importantly, the weight loss values for long and short cores correspond closely with each other. Weight loss was computed for 1 cm intervals in the short core, 10 cm for the long, yet the two curves are a close match. The short core, however, clarifies the sharp decline in organic content, showing that it occurs between 23 and 26 cm. As I will show, this change is critical to dating within the upper silty layer.

Dating

Five radiocarbon dates were obtained from the long core (UW#433, 434, 435 and WSU#1832, 1833; Table 67). All dates are on peat samples from the organic sediments; silty upper and lower layers contained too little carbon for dating. Dates were not corrected to calendric ages because the oldest two exceed the time limits of the Suess Correction Curve (Suess, 1970b; Ralph and Michael, 1974).

A sedimentation rate for the long core was calculated from the five dates by least squares regression. Both linear and semi-log functions were calculated. The linear function,

$$Y = 2566 + 11.3x \quad (\text{Equation 2})$$

had a correlation coefficient (r) of 0.986 and a variance (r^2) of 0.973. This equation approximated the distribution of data points more accurately than the function.

$$\begin{aligned} \log Y &= 8.03 + .0021x \\ r &= 0.969 ; \end{aligned} \quad r^2 = 0.940 \quad (\text{Equation 3})$$

Equation 2 is accepted as the better approximation of sedimentation rate in organic portions of the core, but gives a surface date of 2577 years. This considerable discrepancy between predicted and actual surface ages, assuming the surface is modern, can be accounted for on the basis of core lithology and organic content. Between 23 and 26 cm, lithology changes from silty to highly organic sediment and organic content drops from 60 percent to 28 percent (Figure 46). These differences in organic content suggest variations over time in the rate of sedimentation. Assuming that inorganic material has been blown or washed into the site at a constant rate, the rate of organic sediment deposition was much higher in the period represented by the middle 427 cm of the core than it has been since. Therefore overall sedimentation rates changed abruptly at the 23 cm depth, from 1 cm per 11.3 years (as computed from Equation 2) to a much slower rate.

Table 67. Radiocarbon Dates for Bisonsweh Pond*

Date Number	Origin	Depth	Age in C14 years
UW 435	base of uppermost peat	85-100cm	3433 $\pm$ 120
UW 434	base of second peat	177-192cm	4913 $\pm$ 170
UW 433	surface of alternating series of peat and gyttja	238-247cm	5232 $\pm$ 170
WSU 1833	second base date on core	407-417cm	7473 $\pm$ 98
WSU 1832	surface of lowest peat base date on core	437-447cm	7298 $\pm$ 120

*Dates are presented in the Pennsylvania half-life of 5770 yr.

Extrapolating the line defined by Equation 2, a date of 2826 BP is obtained for the 23 cm level. If a constant deposition rate is assumed for the 2826 years, that rate is 1 cm per 122.9 years. A detailed graph of the weight loss on ignition curve for the upper 23 cm of Core #2 is shown in the left margin of Figure 48 and shows little variation. A chi square goodness of fit test indicated that only one sample (12 cm) differed significantly from the mean weight loss figure for this series of samples. This finding supports the assumption of a constant rate of sedimentation during the last 2800 years (Figure 47).

Technical Considerations

In their attempts to reconstruct the floral composition of past environments, palynologists make a basic assumption: the sample of pollen from a layer of sediment is somehow representative of the flora that contributed pollen to the site (Moore and Webb, 1978:109). A staggering number of factors compromise the validity of this statement and are similar in many respects to the limitations that beset accurate interpretation of the palenontological record. These limitations can be summarized in three general statements: (1) no simple relationship exists between the absolute abundance, biomass or proportional abundance of a taxon and its pollen production, (2) the relationship between pollen production and the influx of pollen grains to a depositional site is complex and not entirely controllable, and (3) the relationship between the concentration or proportional representation of pollen types in a core sample and the concentration and proportional abundance of those same types in the total population of pollen in the depositional site is also complex and only partially understood. Unless these limitations are addressed and the biases they insert into the data can be controlled for to some extent, the meaning of the pollen record from Bisonsweh Pond or any other palynological site will remain obscure.

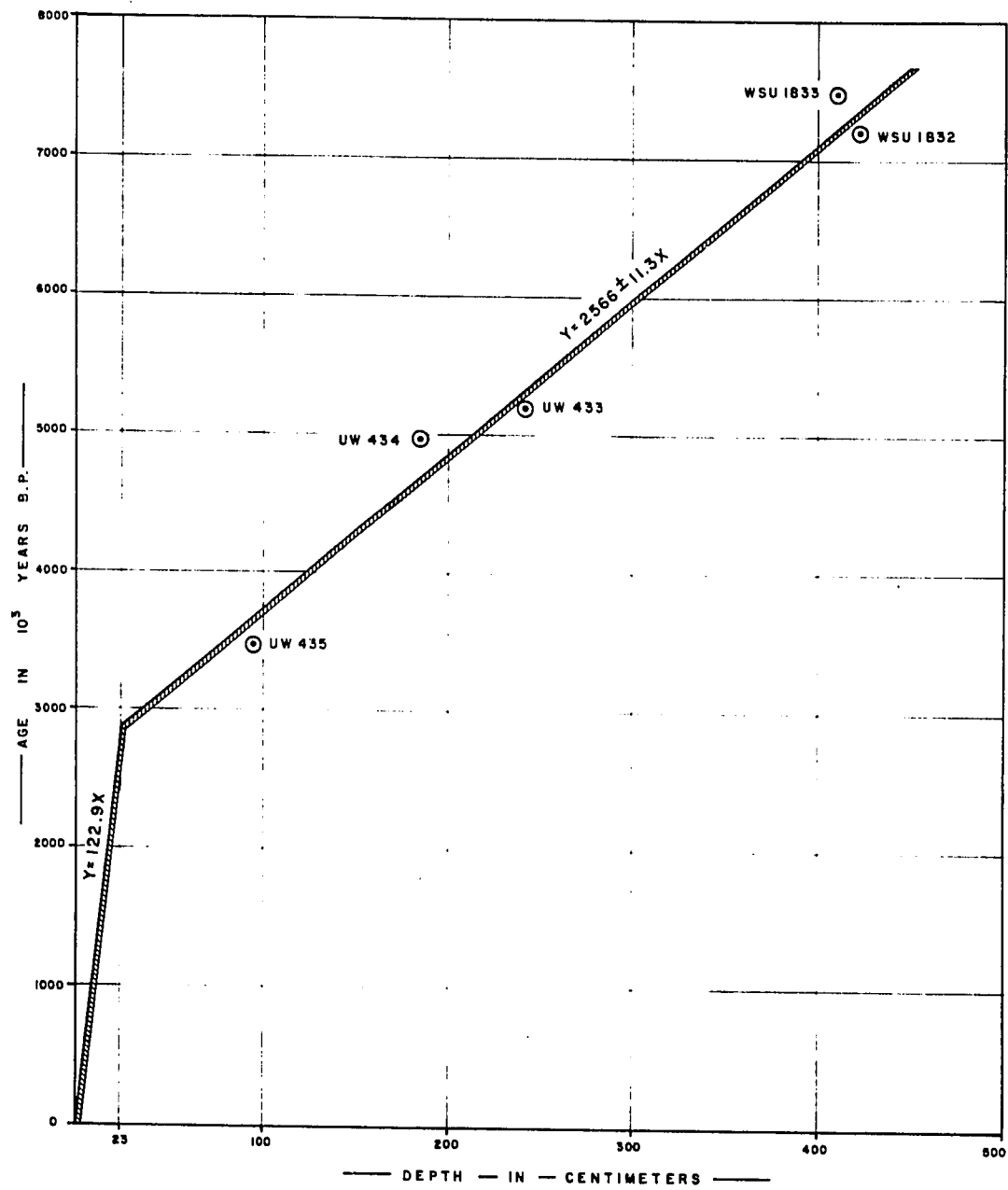


Figure 47. Graph of sedimentation rate for Bisonsweh Pond.

Taxonomic abundance. A corollary of palynology's basic assumption might be that the higher the population or standing biomass of a plant taxon, the greater will be the amount of pollen produced. Likewise, one might expect that the proportional abundance of a plant in the ecosystem will be reflected in its production of pollen. Dominant species should, therefore produce the greatest relative and absolute amounts of pollen; rare taxa the lowest amounts. Various studies have effectively demonstrated the fallacy of such a premise.

In reality, the absolute production of pollen varies from one plant to another. This variation is related, in part, to the strategy for pollen dispersal. Insect pollinating (hymenophilous) plants produce much smaller numbers of pollen grains than do plants pollinated by the wind (anemophilous; cf. Faegri and Iversen, 1975; Moore and Webb, 1978). Anemophilous species therefore contribute the majority of pollen to depositional sites, with hymenophilous pollen represented sporadically, if ever. Both the mode of dispersal and rate of production contribute to this difference. Most trees, grasses, sedges, chenopods, amaranths, and many composites (sagebrush included) are anemophilous, but pollen productivity among them is variable. Pine, oak and alder, for example, produce disproportionately greater numbers of pollen, compared with such trees as fir and cottonwood (Anderson, 1973; Davis and Goodlett, 1960). Sagebrush is far more prolific than are grasses.

Equally great variation exists between rates of pollen production and the population size or biomass of a single species. Although some studies of modern pollen rain have shown a general correspondence between the amounts of tree pollen in a site and the regional abundance of the same trees (R. B. Davis and Webb, 1975; Webb and McAndrews, 1975), some species such as pine, produce more pollen per individual when widely scattered than they do in dense forest stands (Faegri and Iversen, 1975). Apparently, the trees' reproductive effort is promoted by the greater access to solar energy occasioned by isolation. Whatever the reason, the number

of pollen grains dispersed by the trees is not always proportional to their population.

Much less data is available on nonarboreal species, but Daubenmire has investigated the factors affecting flower production in big sagebrush (Artemisia tridentata) and one species of bunchgrass, and the results of his work are informative. Flowering in *Artemisia* and, presumably its pollen production, varies with the substrate into which plants are rooted. Daubenmire (1975) compared plants with approximately equal crown diameter, one growing in a shallow lithosol, the other in a deep loam. The loam-grown plant produced twice as many inflorescences as the other, demonstrating that plant size is less important than substrate to pollen production. The observed difference is probably due to disparity in the water retention capacity of the two soils. Lithosols, with a large particle size and shallow soil column will lose moisture faster than loams. Therefore, flowering and pollen production in sagebrush is proportional to moisture availability. In grasses, plant size is the most influential variable. Bluebunch wheatgrass (Agropyron spicatum), the dominant grass in the sagebrush-bunchgrass steppes of the Pahsimeroi Valley, produces inflorescences in proportion to the diameter of its flower stems. These in turn vary with overall plant size (Daubenmire, 1978).

Thus it is apparent that sagebrush produces far more pollen than grasses and will be overrepresented in the pollen record of Bisonsweh Pond. In addition, pollen production by individual plants of the two types varies for different reasons: substrate (available moisture?) in sagebrush, plant size in at least some grasses. However, these differences should exert a constant influence on the rain of sage and grass pollen into Bisonsweh Pond. It is only necessary to recognize that pollen counts are not a direct measure of plant biomass.

Pollen production and pollen influx. The lack of correspondence between plant and pollen populations is exacerbated by

processes affecting the influx of pollen into depositional environments. Following the research of Tauber (1965, 1967) and Peck (1973), Moore and Webb (1978) list five mechanisms by which pollen may enter a pond or lake. It may be (1) brought down by rain from high altitude wind currents, (2) blown in on wind currents flowing directly over the forest or steppe canopy, (3) carried through the trunk space of plants near the deposition site, wherein extensive filtration occurs, (4) dropped directly onto the water or land surface from plants growing in and around the site, and (5) washed in by streams from various local or regional sources. Pollen may also be washed from a site by rapid throughput of water (Maher, 1963) thereby reducing the representation of pollen types dispersed to the site during periods of peak runoff.

Components of the pollen rain transported by each of these five mechanisms are called the rain, canopy, trunk space, local and secondary components, respectively (Moore and Webb, 1978). Each component will contain differential proportions of pollen produced at various distances from the depositional site. For example, the rain component emphasizes regional pollen production, the canopy is regional and extra local in the main, and the trunk space component includes mostly local and extralocal pollens. Clearly, the frequency with which a particular pollen type will be deposited in a site will depend in part on the proportional influence of each of these components. Should that influence change, variations in the pollen record of a site might be observed that are unrelated to changing vegetation patterns.

A phenomenon which could effect a change in the importance of each component is wind direction (cf. Hansen, 1949; Ogden in Cushing and Wright, 1967). All but the local and secondary components are directly influenced by air movements. For example, a longterm shift from winds blowing through a forest to winds blowing over open steppes would not only have a profound effect on both the filtration effects of the trunk space and the elevation at which the

canopy component is carried, but would also alter the taxonomic composition of the pollen rain as a whole.

The relative impact of each pollen transport mechanism on pollen deposition is also heavily influenced by the size and shape of the deposition site itself (Jacobson and Bradshaw, 1981; Pennington, 1973). For example, differential filtration of pollen by the trunk space of near-shore vegetation will have a more severe impact on small sites, where surrounding vegetation may effectively block out canopy and rain components, than it will have on large sites such as lakes, where most of the water surface is exposed to the atmosphere. Recognizing the importance of site size, Jacobson and Bradshaw (1981:Figure 1) have devised a model of the relationship between the size of a depositional site and the proportional contribution of vegetation growing at various distances to the population of pollen in the site. They argue effectively that small hollows and humus sites contain largely local pollen, produced less than 30 m away. Small lakes with surface areas of 1 to 5 hectares include up to 60 percent extralocal pollen, from plants under a few kilometers from the site, with the remainder equally divided between local and regional sources. Regional flora account for most of the pollen rain to large lakes and extensive bogs.

With respect to problems of pollen transport and their relationship to site size, Bisonsweh Pond is an ideal source of data on the composition of extralocal floras, including the plant communities of the land slide basin, adjacent mountain and alluvial plain (Figure 45). The pond itself has a surface area of approximately 1 hectare and there is no reason to believe wind direction has changed significantly in the past 10,000 years. Winds in the Project Area are convectional, influenced by the temperature gradient between mountaintop and valley bottom. During the day, cool winds sweep off the heights, to be replaced by evening with warmer breezes from the lowlands. Because of this daily reversal of flow, winds alternately carry pollen from highland forest and lowland steppes each day of the flowering season. Effects of these winds should

average out, consistently providing a sample of both steppe and mountainside floras.

Pollen sample and population of pollen in the deposit. Once pollen reaches the depositional environment, a number of additional factors come into play that adversely affect the relationship between the content of pollen entering a site and the samples extracted for analysis. These factors fall into three categories: differential distribution on the sediment surface, differential preservation of pollen types and mixing between depositional strata.

Pollen falling on the water surface is not evenly distributed over the sediment surface. In fact, intrasite variation in the concentration and proportional abundance of pollen types can vary within a single site by a factor as high as 10 (M. Davis et al., 1971, 1973; R. Davis et al., 1969; R. Davis and Webb, 1975; Webb et al., 1978). In general, sediments in deeper water will have a much higher concentration, an effect of sediment focusing by gravity and water currents (Lehman, 1975; M. Davis et al., 1973). The effects of sediment focusing are most extreme in basins with a V shaped profile, and have a profound effect on pollen counts, especially measures of the rate of pollen influx to the site. When these basins are young, sediment is concentrated in the deepest parts of the basin, but as infilling progresses and the lake bottom levels off, this concentration or focusing effect will decline in importance. A core removed from a basin of this kind would show extreme changes in the rate of pollen deposition from bottom to top which were merely an artifact of the depositional environment.

Variations in the distribution of pollen over a sediment surface are also due to differential buoyancy (M. Davis et al., 1971, 1973; R. Davis and Webb, 1975; R. Davis et al., 1969) and proximity of any portion of sediment to local and secondary sources of pollen (M. Davis et al., 1971; R. Davis et al., 1969). Some pollen grains such as pine have air bladders which allow them to float for long periods, but others, like sagebrush, are small, spherical and

tend to sink shortly after reaching the water surface. Buoyant grains will tend to windrow and be disproportionately represented on leeward sides of ponds and lakes and poorly represented in central and windward areas of the sediment surface. Pollen from local plants will be most common in near-shore environments and grains from secondary sources such as streams should be more common in deltaic deposits of a lake bottom than elsewhere in the sediment. These facts point out the profound effect the selection of a coring site can have on the content of a pollen sample.

All pollen types do not preserve equally well. Some types, such as pine (Pinus) and spruce (Picea) are highly resistant to decay, whereas others like cottonwood (Populus) are rarely ever preserved (Sangster, 1964; Sangster and Dale, 1961). The difference is related to the content of sporopollenin in the grain's exine and to the preference of bacteria and other organisms for some pollen types over others (Havinga, 1967).

Differential preservation not only has a pronounced effect on relative proportions of pollen types in a sample, but also varies with the depositional environment (Hills, 1969). Sangster (1964) found that pollens decayed most rapidly in lakes and most slowly in bogs. If the nature of the sedimentary environment changes with time from open water to bog or fen, as is usually the case with pond succession (cf. Mehringer et al., 1977; Nickmann, 1978), the proportional representations of pollen types may undergo changes independently of the parent vegetation.

The final mitigating factor is the mixing that takes place after pollen is incorporated in sediments. Annual water turnover (cf. M. Davis, 1968; Meuller, 1964) and benthic organisms, fishes and rising methane bubbles (R. Davis, 1967, 1974) all cause vertical mixing between sedimentary layers and tend to dampen temporal variations in the pollen spectra. Mixing effects are more evident when a core is sampled at close intervals (R. Davis, 1967), but their effects are not eliminated by increasing sample spacing, only hidden.

Most of the problems I have just outlined should have minor impact on data from Bisonsweh Pond. Because I am only considering the uppermost 23 cm, the effects of sediment focusing approach nil. Working in a single lithographic unit should eliminate problems of differential preservation, or at least reduce them to a constant that affects all samples equally. Differential buoyancy, local pollen sources and secondary deposition are also held constant, as bottom topography has not been changed appreciably by the deposition of such a thin layer of sediment, and the feeder stream and shoreline vegetation have probably held their present positions continuously during the period in question. The most important factor is mixing, which has certainly had an important influence on the clarity of this pollen record. Because I have had to analyze samples taken at 1 cm intervals, the record of vegetation change that results is unlikely to show marked short term variation, but should provide a reasonably good picture of long term trends in the composition of extralocal floras.

Summary. Recent studies have confirmed that "the amount of pollen deposited at one point on a sediment surface is not necessarily proportional to that deposited over the whole surface, nor is the latter related in any systematic way to abundance of plants in the landscape" (M. Davis and Deevey, 1964). Although the problems summarized above strongly argue against facile interpretations of pollen spectra as a direct reflection of changing floras, they are not entirely unsurmountable. Most problem areas are either irrelevant to, exert a constant influence on, or merely reduce the clarity of the pollen record from the uppermost stratum of Bisonsweh Pond. Even the extreme differences in total pollen production and in the variables affecting pollen productivity of grasses and sagebrush can be reduced to constants, such that data on these two taxa can be used as a measure of variations in the ratio of grass to sagebrush in the Project Area.

Modes of Data Presentation

The most common form in which palynological data are presented is the standard percentage diagram, which shows graphically the proportional contribution of each type of terrestrial pollen to the pollen sum. Diagrams also include aquatic pollen types, also calculated as a proportion of the pollen sum (a ration) and any other data which the investigator wishes to present (Figure 48). Histories of local, extra-local and regional plant communities, and even of the pollen site itself are interpreted from changes in the proportions of various pollen types. Although accepted as the best means for summarizing data, the standard percentage diagram poses problems for the analyst which arise from the constraints imposed by the percentage measure itself (cf. Mehringer n.d.; Mehringer et al., 1977; Moore and Webb, 1978). In all percentage calculations, the total percentage for all variables must equal 100 percent, such that the percentage of any one pollen type in a sample will be influenced by the abundance of all other types (cf. M. Davis, 1963; Faegri and Iversen, 1975; Moore and Webb, 1978). Because of this, a percentage increase in one variable, such as pine pollen, will be observed whether the absolute quantity of pine increases while quantities of other types remain constant, the amount of pine increases while other types decrease, or absolute amounts of pine remain stable while other types decrease in frequency. Therefore, it is never possible to say, from just studying the percentage diagram, whether the population of one species or family of plants increases or decreases in the environment.

An additional problem, actually a corollary of the first, arises from the combination of all plant associations (eg. steppe, riparian, montane forest) into a single set of percentage calculations. When one seeks data on changes in the relative abundance of species in a single plant association, the data on that kind of relationship are obscured by having been combined in percentage calculations with other communities.

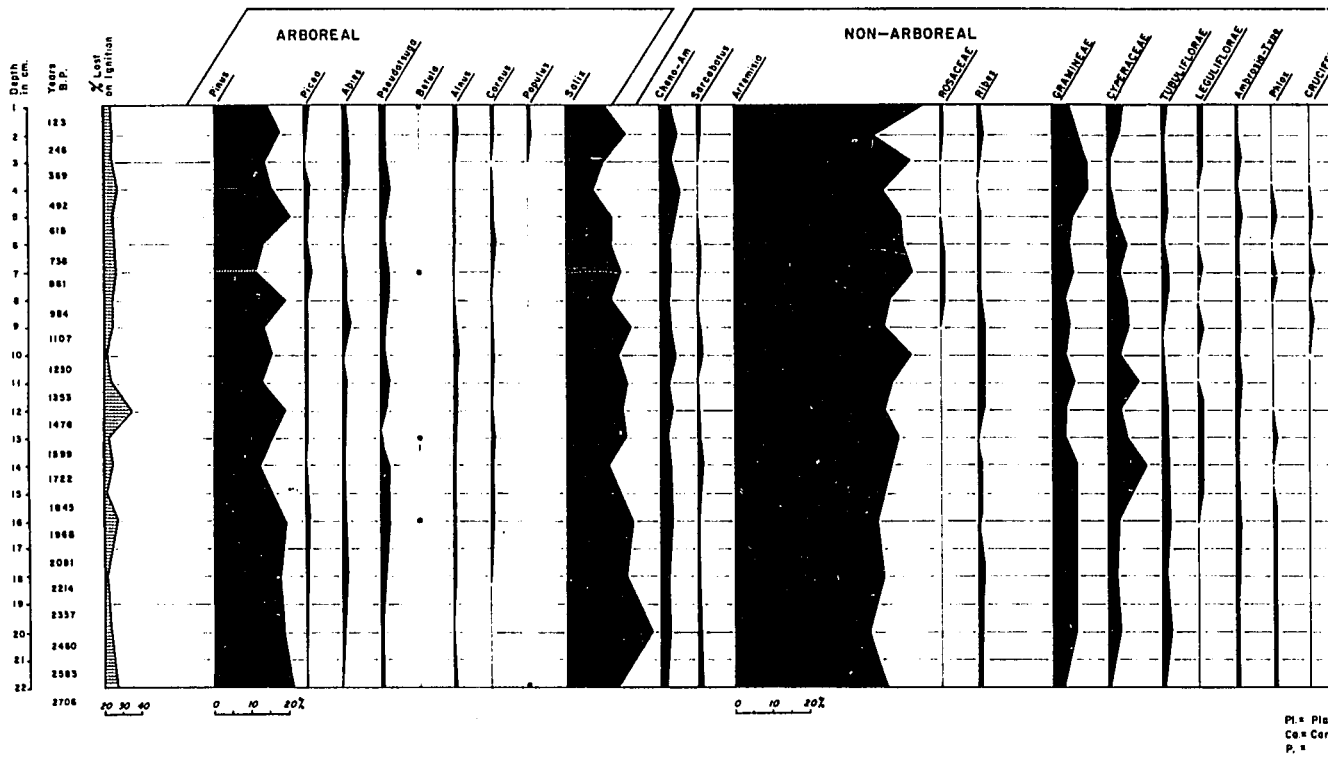
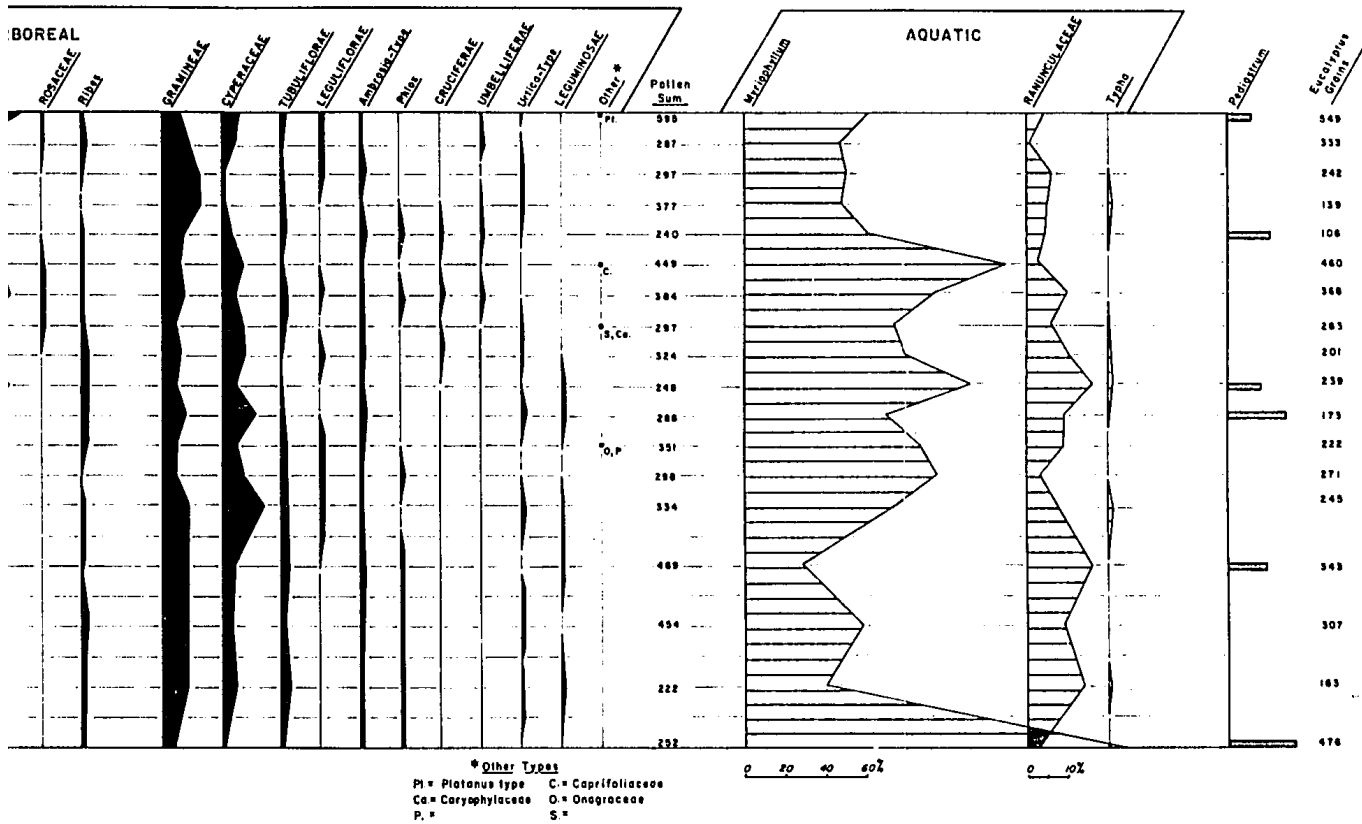


Figure 48. Pollen percentage diagram for Bisonsweh Pond.



ond.

Palynologists have attempted to solve the first problem by substituting another kind of measure, known variously as pollen concentration, absolute pollen influx or pollen deposition rate. Pollen concentration measures the absolute quantity of pollen deposited in a standard volume or area of sediment and is calculated with reference to some parameter outside the pollen sum. That parameter is either a constant volume of extracted sediment (M. Davis, 1965; M. Davis and Deevey, 1964) or a known number of exotic pollen or spores (Benninghoff, 1962; Maher, 1972). Figures resulting from calculations of pollen concentration are expressed as pollen grains per cubic centimeter of sediment or, when time is added to the equation, grains per square centimeter per year. Armed with data on pollen concentration for each pollen type, the analyst should better understand the meaning of change observed in pollen percentages.

Originally thought on theoretical grounds to be superior to percentage measures (cf. Mossiman and Greenstreet, 1971), especially as a gauge of absolute taxonomic abundance and overall densities of vegetation (R. Davis and Webb, 1975), the pollen concentration approach has since been found wanting. Nearly all the biases discussed above are more strongly expressed by this measure than by percentages (Moore and Webb, 1978; Jacobson and Bradshaw, 1981). This is especially true of intra-site variation, caused by such factors as differential sedimentation, differential buoyancy and sediment focussing (M. Davis et al., 1971, 1973; R. Davis et al., 1969; R. Davis and Webb, 1975; Webb et al., 1978; Lehman, 1975). In their recent text, Moore and Webb (1978) advocate abandoning the measure entirely, but many palynologists still cautiously use it to aid in their interpretation of percentage diagrams (e.g., Mehringer, n.d.; Mehringer et al., 1977; O. Davis et al., 1977). On those rare occasions when the many biases can be held constant, pollen concentration might also provide limited information on taxonomic abundance and overall productivity of plant communities.

The second problem of the percentage diagram, that caused by combining all terrestrial plants into a single measure, can be

overcome by using ratios. Ratios can be calculated between two pollen types or between sets of pollen types, thus isolating the proportional relationship between small numbers of taxa. For example, Maher (1963, 1972) and Peterson (1981; Peterson and Mehringer, 1977) have used ratios between subalpine and montane tree species to measure altitudinal movements of tree-lines and vegetation zones. Ratios also are largely free of the biases which limit the applicability of pollen concentration measures (Mossiman and Greenstreet, 1971) but they provide only limited information: a simple contrast between two plant taxa.

None of the three measures, percentage, ratio or pollen influx is without its flaws, and each certainly is capable of providing useful information under the right conditions. As always, which measure or measures an analyst chooses will depend on the problem he or she wishes to solve (Mossiman and Greenstreet, 1971). If some measure of pollen concentration is desired, the many biases it embodies must first be controlled.

Results

In the present study, I am concerned with change in the relative abundance of grass versus sagebrush in the environment around Bisonsweh Pond. The most appropriate measure is therefore a ratio between the two taxa, but to understand the reasons for any changes in that ratio, I have also calculated pollen concentration values for grass, sagebrush, total terrestrial pollen and total steppe pollen (Figure 49). As noted previously, most of the biases that might adversely affect pollen concentration data are minimized in the upper 23 cm of sediment in this site. Pollen concentration can therefore be used with some degree of confidence and, because of the constant rate of sedimentation, can be read as influx of pollen grains per cubic centimeter per 123 years. A standard percentage diagram has also been provided as a data summary.

It is interesting, before looking at the grass/sagebrush ratios to note the overall uniformity evident in the percentage diagram for

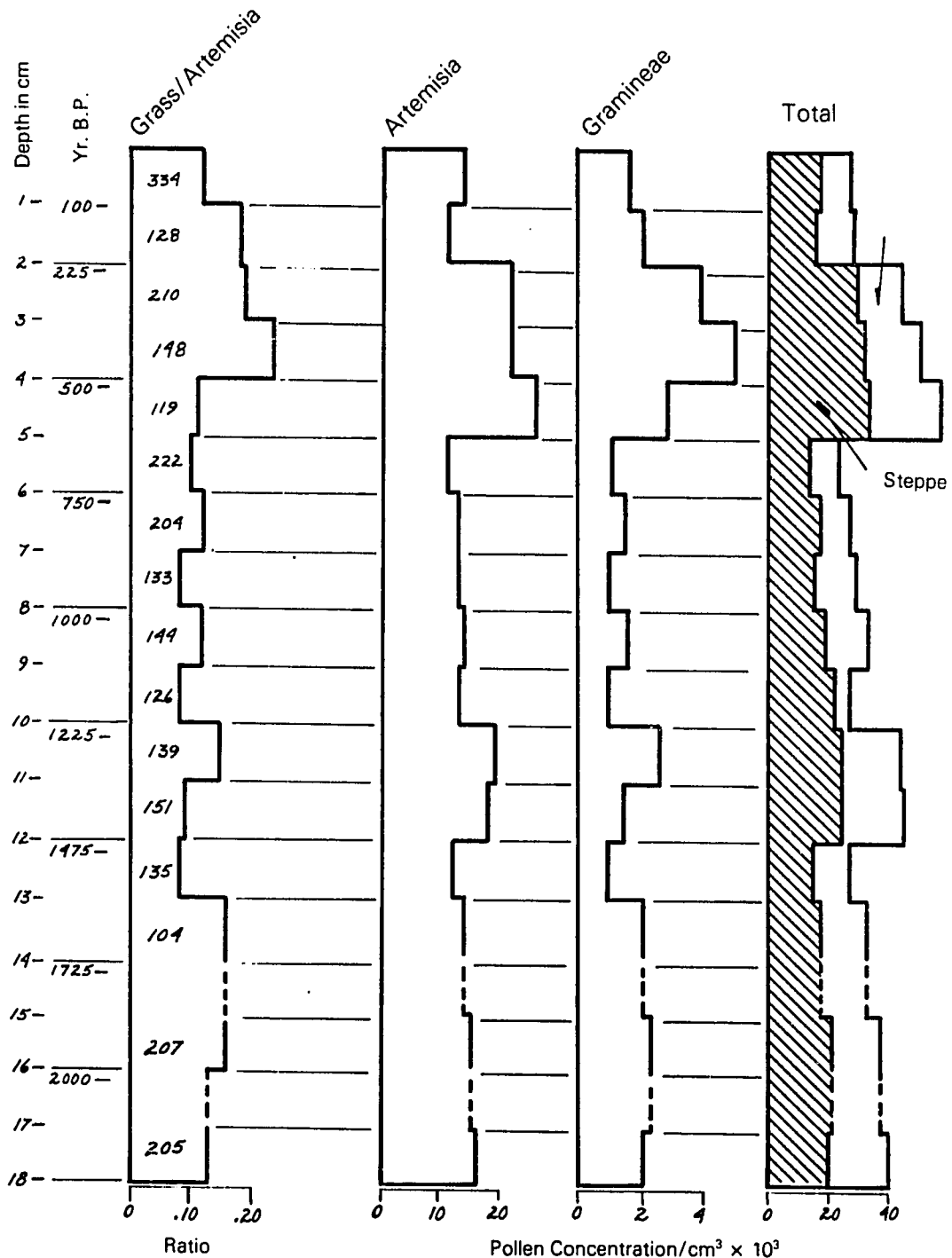


Figure 49. Grass/Artemisia ratios and pollen concentrations for the upper 18 cm at Bisonsweh Pond. Hatched portion of total pollen histogram represents total steppe pollen.

Bisonsweh Pond (Figure 48). It shows so little change in the local pollen rain that the casual observer, passing through the valley would recognize no difference between the steppes of today and those of 400, 1000 or even 2800 years ago. But neither the overall composition of the area's flora nor even that of the steppe is the matter of concern here. What is at issue is the proportional representation of sagebrush versus grass, which, as Figure 49 shows, has undergone some major changes during the last 500 years.

In the centuries before 500 BP, grass/sagebrush ratios consistently remain below 0.160 with values for the pre-1600 period generally higher (mean = .145) than they are from 1600 to 500 BP (mean = .104). A marked jump then occurs at ca. 475 BP (the 4 cm level) from .11 to .24. The ratio remains high (.19) until 100 BP, then declines to .12. A chi square test calculated from raw pollen counts as a measure of the magnitude of these changes showed that the 4 cm and 3 cm levels differed significantly from the mean of all samples ($\chi^2 = 9.78$ and 3.90 respectively; $p < 0.5$). Pollen counts for the 2 cm level, though producing a ratio equal to that of the 3 cm sample are not significantly different, probably because of the lower sample size from this level. In a chi square test comparing adjacent samples 4 with 5 and 1 with 2, the only significant difference was recorded between 4 and 5 cm, ca. 475 BP.

These data show that there is an abrupt increase in the relative abundance of grass to sagebrush during the period between 475 and 350 BP coinciding with the decline in pronghorn and appearance of Bison in Buck Creek Cave. Grass declines to its previous level of importance after 100 BP, but because this change is not abrupt enough to be statistically significant, the resurgence of sagebrush at this time remains equivocal.

Pollen concentration data clarify this most recent change (Figure 49). Graphs for sagebrush, grass, total steppe pollen and total terrestrial pollen all show patterns similar to the ratio diagram; but there are important differences. Concentration is generally lower before 590 BP, except for a brief rise in all

diagrams between 1425 and 1200 BP. The increase in all categories after 590 BP is differentially expressed. Sagebrush and both totals register their largest increase and reach their maximum values during this time. Grass pollen does not, showing only a minor increase at this time, but in the next sample it nearly doubles, while all other categories show a decline. There is a uniform decline in all categories after 225 BP. Grass concentration then continues to drop in the most recent sample, but totals remain nearly constant and sagebrush concentration actually increases. It is this last observation that is the most informative.

If pollen concentration is accepted as an approximation of overall vegetation density (cf. R. Davis and Webb, 1975), the data show that the density of plants in the entire ecosystem begins to increase after 615 BP, with sagebrush at first making far greater gains than grass. After 475 BP the situation reverses and sagebrush decreases slightly as there is a tremendous increase in grass; hence the significant change in the grass/sagebrush ratio. In the next 123 year period (348 - 225), when grass concentration declines slightly and sagebrush remains constant, the ratio also declines. Then, when overall floral density sharply declines (225-100), the relationship between the two plant types remains constant. In the last 123 years (100 - +25 BP) however, sagebrush density actually increases while grass continues to decline. This last is not an artifact of an overall change in the ecosystem, but appears to be specific to these two taxa. Thus the ratio change between the 1 cm and 2 cm samples is the result of an actual change in the concentration of pollen types and, if the relationship between concentration and density is valid, a real decline in the density of grass relative to sagebrush.

There is no reason to suspect that these changes in the local flora are an illusion. A glance at the sums of grass and sagebrush pollen (Figure 49) should suffice to show that no relationship exists between sample size and pollen ratios ($r_s = .30$). Neither has sedimentation rate been a factor (Figure 48, left margin). All

other potential biases have already been neutralized as constants. Grass was indeed a more important member of the steppe flora around Bisonsweh Pond from 500 to sometime after 123 BP than it has been before or since.

Summary

The purpose of this chapter has been to determine whether the change in ungulate faunas, described in Chapter 9 could have been caused by a change in the effective environments of the animals, particularly their food supply. If this hypothesis is superior to the competing, cultural hypothesis, increases in the relative proportion of bison to pronghorn between 460 and 65 BP should correlate with an increase in grass relative to sagebrush. The return of sagebrush-eating pronghorn after 65 BP and concomitant decrease in the number of domestic grazers, cow, horse and sheep after 20 BP should correspond to a resurgence of sagebrush. Pollen data from the uppermost 23 cm of Bisonsweh, a large pond now surrounded by steppe, provided a record of vegetation change which fulfills these expectations. Grass increases significantly only after 475 BP and remains proportionately more important to 100 BP, even in the face of overall environmental deterioration after 225 BP. In the last 123 years, an absolute decline in grass is balanced by an absolute increase in sagebrush. The ecological hypothesis is supported.

Although overall change in the relative abundances of sagebrush eaters versus grazers are accounted for by palynological data, changes in the relative proportions of two domestic grazers are not. Between Periods 7 - 8 and 9 - 10, the horse disappears from local faunas. Because both cattle and horses use the same foods in nearly equal proportions (Table 65), environmental change alone is not a sufficient cause for the horse's fate. The change is therefore a cultural event, an artifact of human activity. The cultural event in question is probably related to an early to mid twentieth century revolution in the transportation field. Internal combustion engines replaced horses as the automobile's popularity accelerated.

CHAPTER ELEVEN

Climate

At this point in the analysis, we have observed changes in the cultural variables: settlement and land use, which take the form of changes in settlement size, functional complexity and hunting patterns in the Lithic Tradition and of overall resource exploitation strategy, settlement size, permanence and function in the Metallic Tradition. These changes correlate with and are plausibly related to changes in the human utilization of various species of large herbivores, which in turn are causally related to shifts in the effective environment, in the form of changing relative proportions of ungulate taxa in natural populations. These changes themselves coincide with and are explained by variations in the relative abundance of the principal forage types: grass and sagebrush. What remains now is to demonstrate whether the observed floral changes represent a response to climatic events, are caused by biological evolution in the floral community or result from human intervention.

Of these three alternatives, the most parsimonious and elegant is that invoking a climatic cause. Plant morphology, at least between native grasses and sagebrush has probably remained constant in the 2500 years of concern to us here, and so too, presumably, has the ecology of each taxon. We are left with a comparison of the cultural hypothesis versus the climatic one, and in this chapter I will test the empirical sufficiency of these alternatives. As before, the human or cultural cause for change is treated as an artifact and as such is only the better alternative if the non-cultural, climatic hypothesis fails to account for the observed change in local flora.

In testing the climatic hypothesis, I shall first consider the ecology of grass and sagebrush, paying particular attention to the

effects on growth of fluctuations in temperature and precipitation. I then present current evidence for long-term changes in atmospheric temperature, summarized from numerous sources on Northern Hemisphere paleoclimates, along with tree-ring and palynological evidence for regional shifts in annual precipitation. Finally, I present information from local tree-rings to affirm the applicability of regional reconstructions of precipitation to the Project Area.

Sagebrush and Grass Ecology

Grass

The dominant native grasses of Central Idaho's steppes are all Festucoid species: Agropyron specatum, Festucoid idahoensis and Poa sandbergii. The annual growth cycle of festucoid grasses has been summarized by Evans and his co-workers (1964). During cold winter months, when leaf growth is subdued, strong root growth occurs at the near freezing temperatures maintained beneath even a moderate snow pack. With the warming of soils in spring and exposure of plants to sunlight, leaf growth accelerates rapidly, stems elongate and inflorescences appear. After flowering in late spring or early summer, growth of both leaves and roots declines into dormancy, a response to the heat and moisture stress of summer. Growth resurgence then occurs in the fall when temperatures and precipitation return to more favorable levels.

Throughout the spring and summer, growth is strongly controlled by temperature and moisture. All festucoid species grow best at lower temperatures, actually requiring relatively low temperatures during the spring period of growth and flowering (Daubenmire, 1972). For many species of Festuca and Poa, optimal day/night growing temperatures average 21° C/12° C, with considerable leaf growth continuing at temperatures as low as 12° C/4° C (Evans et al., 1964). Soil temperature seems to be the most important factor here (eg. Daubenmire, 1972). Even when daytime air temperature exceeds the

optimum level, cold night, by maintaining a low soil temperature, will continue to favor a high rate of growth.

Extremely high daytime temperatures or high aridity initiate dormancy in perennial grasses. The earlier in the summer these extremes are reached and the longer they persist in fall, the lower will be the biomass of grasses. Seedlings are especially sensitive to heat and their summer survival is inhibited by high temperatures (Evans et al., 1964). Two facts are important to assimilate here. First, high temperatures, even in the absence of reduced soil moisture, will inhibit growth of already established plants. Second, very warm periods reduce the reproductive success of festucoid species.

In stressing the importance of temperature I do not intend to underplay the significance of moisture. In fact, generally speaking, the primary productivity of North American grasslands is proportional to precipitation (Lauenroth, 1979). Coupland (1959) observed that in the mixed prairies of Southern Alberta and Saskatchewan, a precipitation increase of 20 percent coupled with a temperature decline of 3 - 5°F below the mean, lead to 16 percent lower evaporation and a doubling of the ground covered by Agropyron and Stipa. An even greater change in grass cover was observed by Tomanek (1959) who recorded a five-fold variation between wettest and driest years in Kansas. Finally, in the steppes of eastern Washington, grass dominated plant associations occur in cooler, moister environments where water content of soils remains fairly high for most of the year (Daubenmire, 1972).

In summary, grass growth and successful reproduction are enhanced by cool, especially cool-moist spring and summer conditions, and are inhibited by high temperatures and drought.

Sagebrush

The two dominant species of Artemisia in steppes of the Pahsimeroi Valley are Artemisia tridentata (big sage) and Artemisia arbuscula (low sage). Here, as elsewhere in the west where these

two species are found in competition (eg. Fosberg, 1963; Driscoll, 1964; Sabinski et al., 1978), Artemisia tridentata prevails on finer soils, and Artemisia arbuscula on coarser-grained substrates. The reason for this difference is presumed to be that Artemisia arbuscula is the more drought resistant species (Sabinski et al., 1978).

Artemisia, generally viewed by range managers as a pest species, has been the subject of few ecological studies, with most concentrating on Artemisia tridentata.

In eastern Washington, steppe associations dominated by A. tridentata are restricted to the warmest, driest areas (Daubenmire, 1972). Compared with grass dominated communities, these associations develop in areas where soils are warmer earlier in spring and where summer temperatures reach higher extremes. They also have lower soil moisture, with later dates of water penetration to 1.0 m and earlier dates of water depletion at this depth.

Artemisia seedlings cannot tolerate water saturated soil. In most cases, if the soil around newly sprouted seedlings remains saturated for more than four days, most seedlings do not survive later periods of water stress (Daubenmire, 1975).

To summarize, Artemisia tridentata is favored by warmer, drier conditions. A. arbuscula, which is apparently more resistant to drought, must certainly follow this same pattern.

Grass and Sagebrush in Competition: Climatic Test Implications

From the foregoing it should be apparent that in a competitive relationship between festucoid grasses and sagebrush, grass will be favored by cooler spring and summer temperatures, especially when these are accompanied by higher levels of available moisture. Warmer spring-summer temperatures are better for sagebrush and give it greatest competitive advantage when they coincide with drought. Dendroclimatic data from the project area provide an indirect measure of spring-summer precipitation and in combination with data on global temperature variations, permit us to assess whether

climatic conditions during any time interval would have favored sagebrush or grass.

We will expect increased grass, as indicated by the pollen analysis, to coincide with cooler-wetter intervals; sagebrush with the inverse.

Presumably, when an interval occurs during which strong competitive advantage is not conferred on either taxon, the status quo, whatever it may be, that developed during the most recent prior interval that did confer advantage to one or the other taxon will be maintained. For example, when a warm dry interval, which enhances the competitive status of sagebrush is followed by a cool but still dry period, sagebrush can be expected to maintain its advantage until conditions favoring grass develop. The important intervals are therefore the extremely wet, cool and warm, dry times, the after-effects of which persist until the status quo is upset by another set of extreme conditions (cf. Derzeevskii, 1969).

Climatic Change: 3000 BP to the Present

Because climate is not directly measurable in the paleontological record, climatic changes must be indirectly reconstructed through a measurement of past values of one or another dependent variable and the assumption that the correlation of these variables with climate can be extrapolated into the past. Correlations between climate as an independent variable and some chemical, physical or biological phenomenon as the dependent variable are the foundations of paleoclimatic science.

Among the climatic phenomena we observe today, those most often measured in paleoclimatic studies are temperature and precipitation or some combinations and/or manifestations of these two principal factors, (eg. snowfall, growing season length and evaporation rate). Dependent variables include stable and radioactive isotopes of various light elements, geomorphologic features, ice melt patterns, measures of pollen influx and proportion and tree-ring analyses (cf. Frenzel, 1973; Lamb, 1977).

Temperature

Studies have shown that atmospheric temperature has varied on a global scale partially in response to variation in the output of solar energy, (cf. Denton and Karlen, 1973; Lamb, 1977; Epstein et al., 1970), whereas precipitation patterns have a greater tendency to be influenced by local air currents, water bodies and convection patterns. Because temperature variation is largely a global phenomenon, measurements of changing temperature elsewhere in the Northern Hemisphere, if as expected they show a coincident sequence of changes, can be taken as applicable to the project area as well. In the following brief sections I explore six bodies of data, including short term Carbon 14 variation, oxygen isotope ratios, ice melt sequences, glacial chronologies, pollen transfer functions and tree-line fluctuation (as indicated by pollen analysis and dendro-chronology). Except for the Carbon 14 record, all data come from latitudes equal to or north of the Project Area.

Carbon 14. Shortly after the Carbon 14 dating method was developed, researchers began to observe that there were often significant discrepancies between Carbon 14 ages and true calendric dates, and that there was a correlation between short term variations in the atmospheric inventory of Carbon 14 and solar activity and terrestrial climates (DeVries, 1958; Stuiver, 1961; Stuiver and Suess, 1966). Specifically, there were inverse relationships between Carbon 14 and sunspot activity and between Carbon 14 and glacial activity and temperature (Denton and Karlen, 1973; Stuiver and Suess, 1966).

The reason for this relationship is supplied by the hypothesis which currently best explains short term variations in atmospheric Carbon 14. The solar wind created by sunspot activity creates a weak magnetic field around the solar system, which repels some of the cosmic radiation entering the system from the galaxy at large (Suess, 1970a). Because Carbon 14 is produced through the cosmic ray bombardment of N14, increased sunspot activity reduces cosmic

radiation and slows the production of Carbon 14, leading to a lowered Carbon 14 pressure in the atmosphere. Sunspot activity is an indicator of, if not the cause of increased production of solar energy which upon reaching the earth, would tend to raise atmospheric temperature. Presumably, short-term variation in Carbon 14 (not to be confused with long-term trends in Carbon 14 abundance; Ralph and Michael, 1974; Suess, 1970b), indicate variations in solar output, insolation to the earth, and variations in terrestrial temperature. A rise in Carbon 14 abundance correlates with lower temperature; lower Carbon 14, with higher temperature, because both are caused by the same solar phenomenon.

The Carbon 14 record is shown in Figure 50. Values represent percent variation from normal, long-term trends and are taken from Stuiver and Suess (1966) and Suess (1970b; Ralph and Michael, 1974), who developed these data by comparing Carbon 14 ages against dendrochronological dates. There are two long, cool intervals, the first from around 3000 to nearly 2500 BP and the second from 550 to 100 BP, and two shorter cool periods, 2250 - 2350 BP and 1300 - 1000 BP. Otherwise, conditions have been warm, with the highest temperatures indicated at around 2000 - 1900, 700 - 800 and after 100 BP.

Oxygen Isotope Ratios. Oxygen 16 and 18 are two stable isotopes with chemical characteristics which differ in relationship to the temperatures of precipitation and condensation of the compounds they comprise. Studies have shown that water containing Oxygen 18 condenses at a higher temperature than Oxygen 16 (Epstein et al., 1970) and that Oxygen 18 containing carbonate molecules precipitate from sea water at higher temperatures than those without Oxygen 18 (Emiliani, 1955; Epstein et al., 1970). Therefore, carbonates forming the skeletons of foraminifera deposited in deep ocean sediments, and water falling as snow or rain and incorporated in ice packs or the tissues of living organisms will be enriched in Oxygen

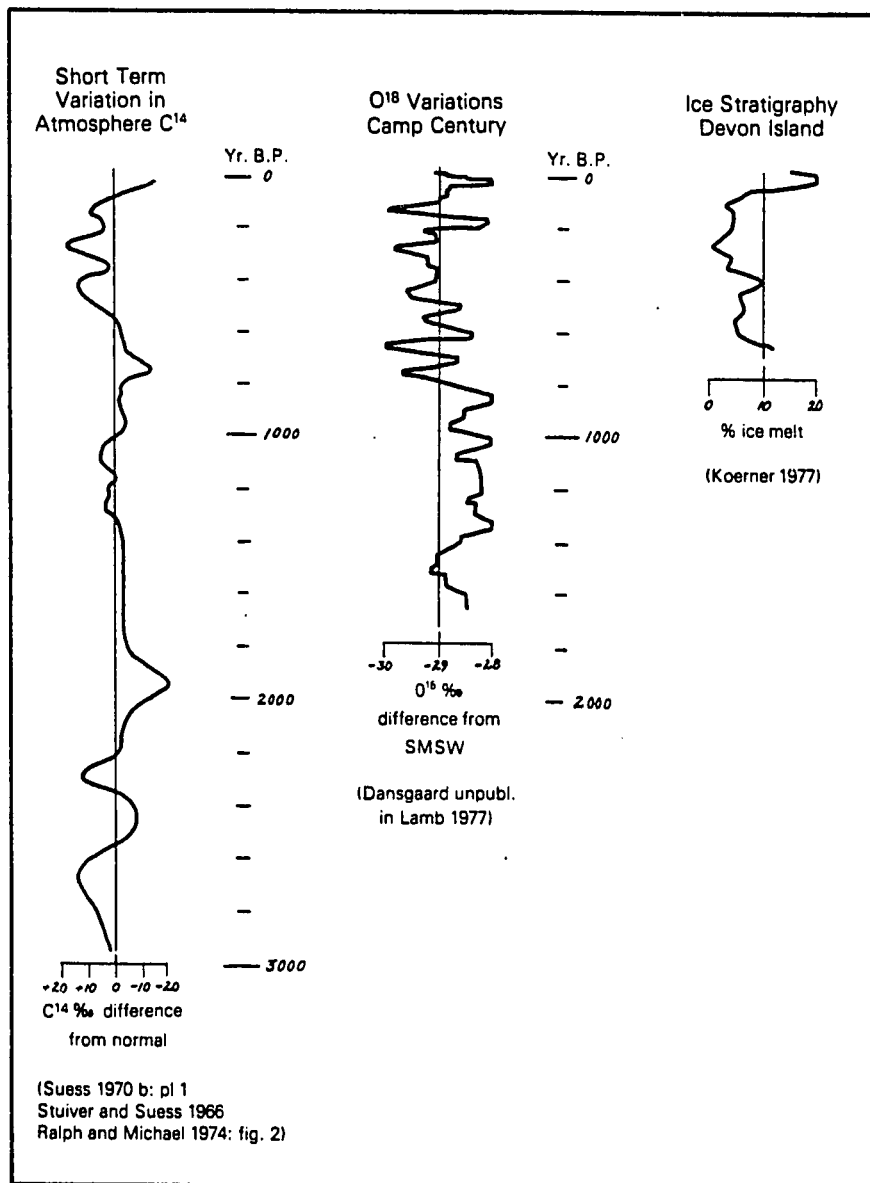


Figure 50. Carbon 14, Oxygen 18 and ice stratigraphy data, each used as an indicator of fluctuations in paleotemperature. See text for discussion and explanation.

18 if formed at higher temperatures, impoverished if formed at low temperatures.

Based on this principle, studies of the Oxygen 18 content in deep sea cores and polar ice have shown a worldwide correspondence in temperature over the last 500,000 years (Dansgaard et al., 1970a, b; Duplessy, 1978; Emiliani, 1955, 1972; Epstein et al., 1970). A more detailed record of the most recent glacial interval has been developed from an ice core taken at Camp Century, Greenland (Dansgaard et al., 1970a,b) which in its most detailed form registers temperature fluctuations over the past 1700 years (Figure 50). Dating of this sequence is problematic, having been calculated from a mathematical model of compression and ice flow which assumed a constant rate of input. Therefore, an exact correspondence between this record and the tree-ring dated Carbon 14 sequence cannot be expected, but the two are similar.

There was a long, warm period prior to 750 BP followed by fluctuating warm and cold intervals of short duration lasting to 500 BP. A long, cold spell followed until 100 BP, containing one short warm episode at 150 - 200 BP. The modern period has been comparatively warm, but has shown a recent cooling tendency. Studies of the Oxygen 18 content of oak wood from various sites in Northern Europe (Libby unpublished data cited in Lamb, 1977) produced similar results, with the cool period lasting from around 500 to 50 BP. During that time, coldest temperatures occurred from 350 - 50 BP and the late warm episode dated by Dansgaard (Lamb, 1977, Figure 17.12) at 150 - 200 showed up between 175 and 225 BP.

Ice melt. Observing a correlation between the percentage of ice in annually layered ice cap deposits of Devon Island in Northeastern Canada and the extent of open ice in nearby Queen Elizabeth Channel, Koerner (1977) concluded that the relative proportion of ice melt layers to firn (crystalline snow) was proportional to mean summer temperatures. Warmer summers mean a longer, more intense

period of melt at the firn surface and cause an increase buildup of ice below the surface. Analysis of the percentage of ice in multi-year intervals of a 150 m core removed from the Devon ice cap (Figure 50) revealed that during the nearly 700 years represented by the core, low ice percentages occurred from 600 to 50 BP with the lowest recorded between 350 and 50 BP. Greatest ice melt occurred during the last 75 years, with the maximum between 20 BP and +10 BP. The correspondences between this sequence and those produced by the Oxygen 18 method are striking.

Glacial chronology. Historic records from Europe (Lamb, 1966, 1977) provided ample evidence that periods of glacial advance are most closely correlated with intervals of atmospheric cooling. Denton and his co-workers (Denton and Karlen, 1973; Denton and Porter, 1970; Porter and Denton, 1967; see also Mahaney et al., 1981) have attempted to correlate worldwide glacier fluctuations based on radiocarbon and lichenometric dates on moraines and other glacial features. During the last three millenia there have been two major periods of glacial advance, corresponding to the Temple Lake and Gannett Peak stades of the Rocky Mountain sequence (Richmond, 1965). The first of these intervals peaked around 2800 BP in North America (Porter and Denton, 1967), and had receded before 2400 BP (Denton and Karlen, 1973). The second, more intense episode of glaciation includes a brief, minor and by no means universal advance around 650 BP, a period of recession lasting until 460 BP and a major advance from 400 to between 50 and 100 BP (Denton and Karlen, 1973:155). In most areas, this latest glaciation included a series of fluctuations with the last minor advances coming at 60 and 34 BP. Alpine glaciers today are confined to extreme altitudes and latitudes.

A third, brief interval of glacial activity lasting from 1050 - 1250 BP, was confined to western North America but was not universal in that area. This cold period is circumscribed by the Carbon 14 peak of 1300 - 1000 BP.

Transferring from glacial events to temperatures, the chronology of North American glaciation (Figure 51) shows cold conditions from 3000 - 2400 BP, a long warm interval to 460 BP with two minor cold spells within it, and a second, more intensely cold period lasting between 460 and 100 - 50 BP. Modern conditions are warm.

Pollen transfer functions and July temperatures. The use of mathematical transfer functions to retrodict weather conditions from pollen type percentages was pioneered by Webb and Bryson (1972). Their analysis applied canonical correlation algorithms to a comparison between the percentages of pollen types from modern collection sites and climatic records from nearby weather stations. The resultant multinomial equations were then used to reconstruct climatic changes for the post-glacial period in north-central North America.

Subsequently, several investigators, though preferring multiple regression to canonical correlation, have used transfer functions to reconstruct mean July temperature, the variable with the highest correlation to pollen type percentages (Andrews et al., 1981; Bernabo, 1981; Buchner, 1980). Andrews and his associates (1981) have attempted a temperature reconstruction for Baffin Island, Buchner (1980) for Southwestern Alberta and Bernabo (1981) for Michigan. Of the three, only Bernabo's results are especially useful. The Baffin Island reconstruction is at considerable variance with both the temperature changes indicated by fluctuations in the spruce\tundra border (Nichols, 1967) and by the Devon ice core (Koerner, 1977; see above) and is therefore of questionable validity. Buchner's (1980: Figure 4) data, though indicating a series of warm-cool fluctuations that is nearly identical to those I have discussed previously, is undated and therefore of marginal value.

Bernabo's findings by contrast are well dated and show some degree of internal consistency. Of the four reconstructions he was

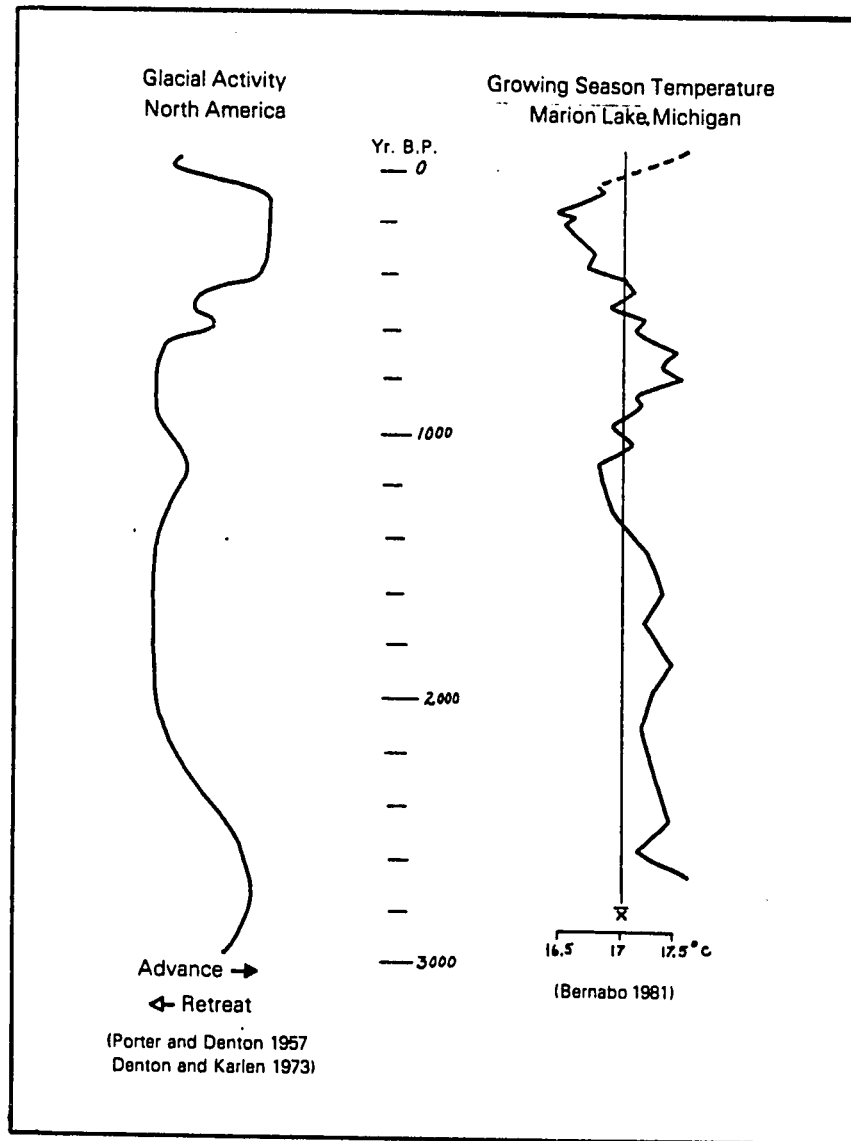


Figure 51. Further indicators of paleotemperature change in North America: Glacial chronology and the Marion Lake paleotemperature record (derived through a pollen transfer function).

able to produce, Bernabo considers his long Marion Lake record to be the most accurate indicator of variations in July temperature (Figure 51). This reconstruction shows warm conditions prior to 1400 BP and a brief cool episode lasting until 1150, when warmer conditions return. A second, longer and more intense period of cold occurs from 500 - 100 BP, after which temperatures rise again. These results are similar to those obtained by other means, but the cool interval of 2400 - 3000 BP is not represented.

Tree lines and tree rings. The principal variable limiting tree growth and survival at elevations near tree line is temperature (La Marche, 1974a). The low, daytime temperatures associated with extreme altitude exert a strong influence on the net rate of photosynthesis in leaves and consequently on tree growth and survival. A colder and/or shorter growing season at tree-line will reduce tree growth temporarily and, if persisting for many seasons in succession, will lead ultimately to the death of trees and a depression in the tree line. Conversely, warmer conditions permit higher growth rates (wider tree rings) and the establishment of new seedlings at altitudes above the existing tree line. Persistent warm temperatures promote seedling survival and lead to a rise in the tree line. Studies of tree-line fluctuations and variations in the width of growth rings in high elevation trees are, then, valid means for measuring changes in atmospheric temperature.

Tree line studies bring our investigation closer to the project area: the White Mountains of California (La Marche, 1973, 1974a) and the La Plata range of southwestern Colorado (Petersen, 1981). On Sheep Mountain in California, La Marche (1973) observed declines in the elevation of successful seedling establishment at 3400, 1100, and 450 BP, with similar, though not coincident declines on nearby Campito Mountain. Actual death of already established trees could not be discerned for older incidents of decline, but most recent tree deaths clustered around 450 BP. La Marche concluded that an

abrupt climatic deterioration had occurred between 1300 and 1600 BP, but drew no conclusion from the events of 450 BP or 3400 BP.

Ring widths in bristlecone pine from the same area show a similar sequence, indicating a cooling from 3300 - 2200 BP, warmer conditions to 1600 BP, cool again to 850 BP, a warm interval ending around 700 BP and a return to warmer conditions after 100. The coldest period in the sequence seems to have been 520 and 100 BP (La Marche, 1974a, 1974b).

Petersen's (1981) information results from the pollen analysis of two sites below tree-line. His data show lowered tree lines at 2800, 1400 and 750 - 150 BP which he interprets as indicative of cool summers. Major tree line advances occurred between 2500 and 1500 BP and in the last 100 years, as a result of warmer conditions.

Temperature: Summary. Although the various reconstructions of paleotemperature which I have summarized (Figures 50 & 51) do not show identical sequences of warm and cool climates, some strong correlations are evident. Beginning at 3000 years BP, worldwide temperatures were relatively cool, a condition that persisted until between 2400 and 2200 BP. A long, warmer interval then followed, ending between 450 and 550 BP. Some records show a slightly cooler period between 1400 and 1000 BP, but nowhere is this climatic deterioration extreme. The coldest period in the last three millennia lasted from 450 to between 100 and 50 BP. Nearly all evidence is in agreement on this, as it is on the fact that the modern period is one of the warmest in recent times.

Precipitation

Before presenting moisture data derived from my study of tree-ring variations in the Pahsimeroi Valley, it is useful to consider two lines of evidence of more regional scope; tree-ring studies of the entire west (Fritts, 1965; Stockton and Meko, 1975) and the results of a palynological study of Wildcat Lake, southeastern Washington (O. Davis et al., 1977) provide this evidence.

Dendroclimatology (cf. Fritts, 1971, 1974, 1976) is based in general on mathematical correlations between tree-growth expressed as standardized ring width indices and some set of climatic variables. In the case of Fritts' (1965) reconstruction of climatic patterns in western North America, he assumes that ring width correlates with moisture stress, wide rings meaning moist or cool-moist years and narrow rings, dry or warm-dry years. One of the tree-ring sites used by Fritts was in the vicinity of the Pahsimeroi Valley (Schulman, 1956) and a summary of moisture changes based on that site is presented in Figure 52 for the period 450 - +10 BP. Although the record shows a marked degree of fluctuation, drier periods are evident from 450 to 420, 370 to 350, and 300 to around 50 BP. The 420 - 300 BP interval is primarily moist as was the 50 - 20 BP (1930 - 1940 AD) very clearly.

Stockton and Meko (1975) considered only the past 250 years, correlating tree-ring indices with the Palmer Drought Severity index. Their results correspond to those of Fritts and indicate frequent, long, severe droughts in the 1930's and during the 18th and 19th centuries. Wettest periods clustered between 1907 and 1916 (Figure 52).

Wildcat Lake provides a distinct form of climatic measure, that of water depth. Various species of aquatic plants previously inhibited by high salinity levels, show a sudden bloom after 450 BP and Cyperaceae (sedge) pollen increases in proportional abundance after 500 BP. Davis, Kolva and Mehringer (1977) interpret this to mean an increase in water depth during the last 400 - 500 years as a result of increased precipitation, reduced evaporation rates or both.

Precipitation: Summary. Previous studies have shown that western North America experienced dry climatic conditions for some time prior to 500 BP. The following period of increased precipitation lasted for 200 years, after which conditions were dry until

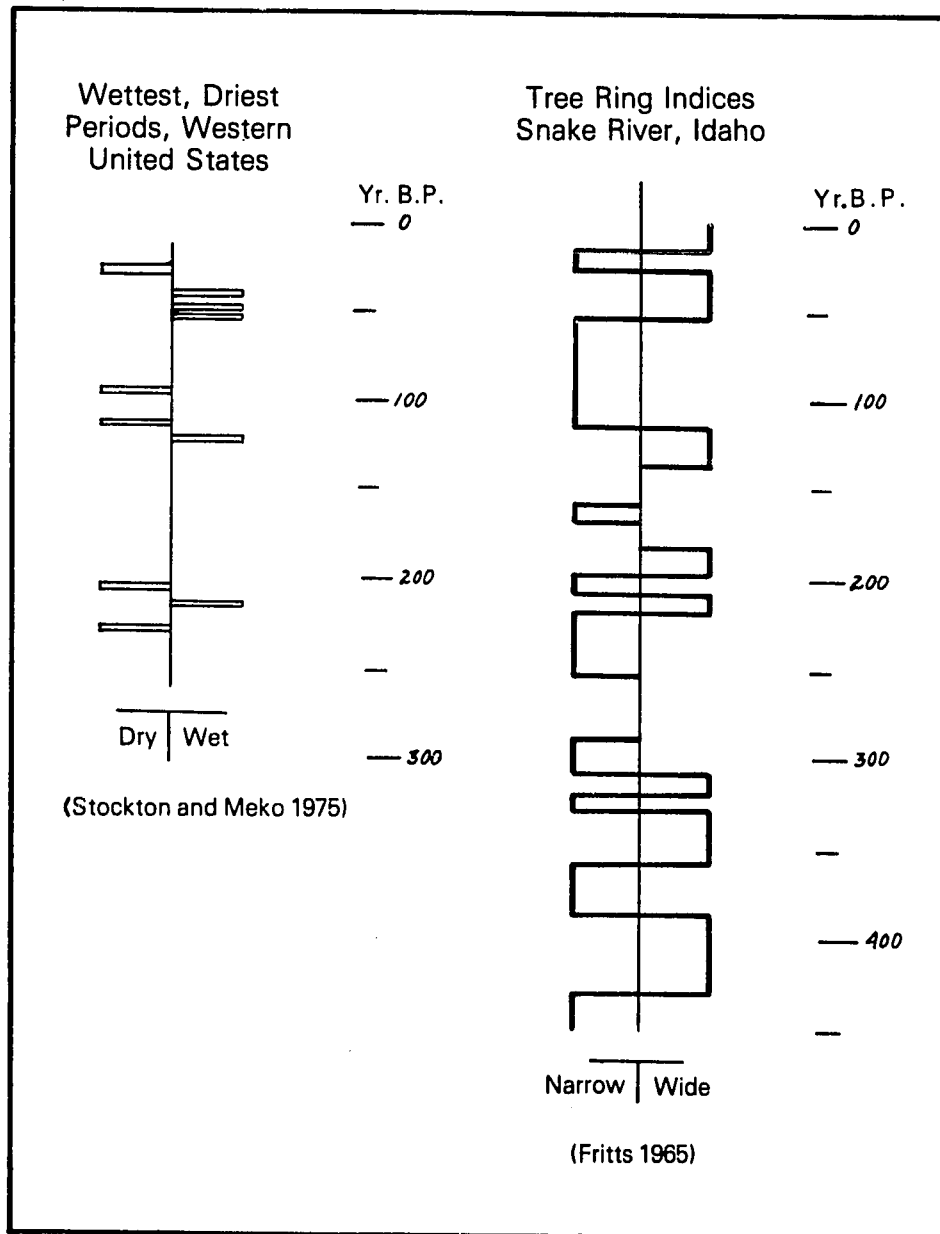


Figure 52. Records of change in precipitation/moisture availability for the period 0 to 450 BP in western North America as interpreted from tree-ring data.

50 - 75 BP. Higher precipitation of the 50 - 25 BP interval was interrupted by a severe drought that lasted from 10 to 20 BP.

Doublespring Dendroclimatology: A Record
of Local Moisture Availability

Reconstruction of a precipitation or at least available moisture record for the project area entailed the use of dendro-climatological methods. At the outset of my study, only two tree-ring chronologies had been acquired from the vicinity. One of these, a record spanning the years 1569 to 1966 AD was from Douglas fir growing along the south side of Salmon River between the confluences of the Pahsimeroi and Lemhi Rivers (Drew, 1975:23); the other is a much longer record (1286 - 1950 AD) from the Snake River Plain (Schulman, 1956). Neither was entirely appropriate to my needs. The Salmon River chronology was too brief and the Snake River Plain series, although long enough to cover the change from Lithic Tradition Period 5 to Period 6, was from an area that is topographically and climatically distinct from the Pahsimeroi. I therefore collected tree-ring data from sites in the project area to develop a truly local reconstruction of moisture availability.

Subsequent to my research, an additional tree-ring chronology has been developed for the Salmon River Mountains, near Challis (Pearson, 1978). This 900 year Douglas fir record has since been the subject of an analysis by Hackenberger (nd) who used it to develop a reconstruction of Salmon River runoff. I shall discuss Hackenberger's results along with my own.

For the local reconstruction I gathered tree-ring cores from four sites in the Doublespring Canyon vicinity and one along Mahogany Creek (Figure 53). Site selection, coring, core processing and data analysis procedures generally followed Fritts (1974, 1976) and Stokes and Smiley (1968), with exceptions noted. Cores were taken from limber pine (Pinus flexilis) and Douglas fir (Pseudotsuga menziesii glauca) and have produced 1013 year and 513 year records, respectively, of change in local moisture availability.

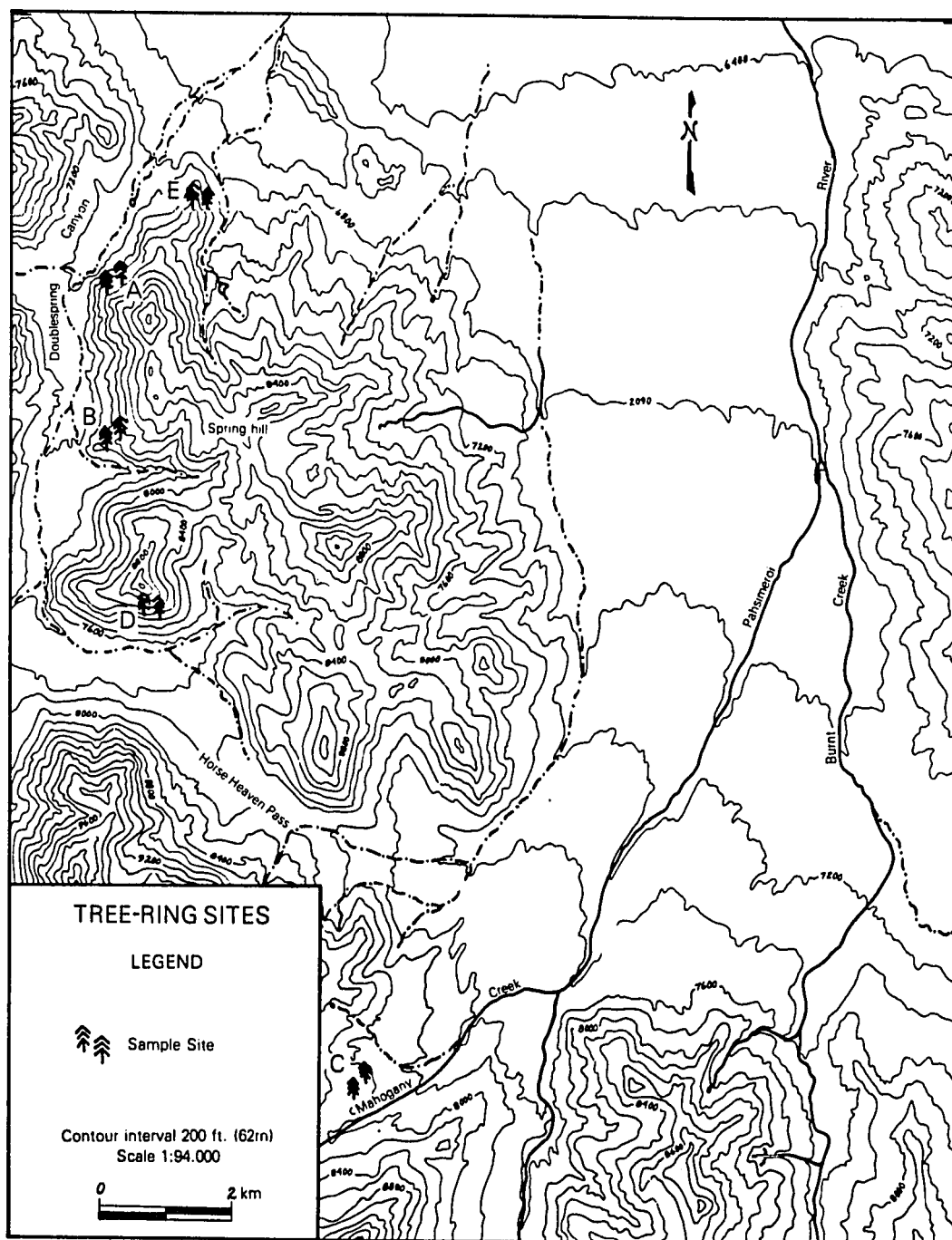


Figure 53. Locations of tree-ring sites in and around Doublespring Canyon.

Site selection. Fritts (1971, 1974, 1976) recommends that, when moisture is the variable one wishes to reconstruct, trees producing the most useful ring series are those conifers growing at or near the lower tree-line on sites exposed to sun and wind or having a low capacity for water retention. At sites such as these, high temperatures and low precipitation combine in especially unfavorable years to cause acute water stress. This stress results in a lowered rate of net photosynthesis, leading to poor growth and the production of what appear to the analyst as narrow or incomplete growth rings (Fritts, 1974: Figure 5 & 6). Within these arid growth sites, the trees which can be expected to show the maximum amount of climate-related variation in ring width, and to be least affected by intra- or interspecific competition and microclimatic forces, are those isolated individuals with rounded crowns and the gnarled look which bespeaks a generally stressful existence. The most useful of these trees produce ring series showing high degrees of between-ring variation (high mean sensitivity) and between-tree correlation in ring width pattern. A low degree of serial auto-correlation within individual ring series is also preferred, since high auto-correlation reflects long-term ecological responses to climatic change rather than short-term variations in moisture availability. Trees which meet these criteria have responded to regional climatic variation much more than to local ecological conditions and can be expected to provide the highest degree of correlation between ring widths and climatic variables.

Exploratory cores were taken from all five sites (Table 68), with at least three trees cored in each site, and examined for the characteristics outlined above. Preliminary examination showed that the limber pine of Site C had a low mean sensitivity and that between-tree correlation was also poor, but all other sites appeared to be favorable. These four sites are all at or near the lower tree-line on the walls of Doublespring Canyon and its tributaries. Three, A, B and E are Douglas fir groves on shallow and/or loose

Table 68. Basic Data on Pahsimeroi Valley Tree-ring Sites

Site	Species	Exposure	Substrate	Elevation in meters	Topography	Mean Sensitivity & Intercorrelation	Cores Taken	Analized
A	<i>Pseudotsuga</i> m.	N	Silty talus	2210	Steep slope near base of canyon wall	(high) high	20	0
B	<i>Pseudotsuga</i> m.	N	Shallow, coarse sandy loam	2340	Ridge crest	.2788, high	24	9
C	<i>Pinus flexilis</i>	Total	Glacial drift	2460	Rolling	(low) low	8	0
D	<i>Pinus flexilis</i>	S	Loose, loamy talus	2700- 2770	Steep slope	P.f. .4706, moderate	22	9
	<i>Pseudotsuga</i> m.					P.m. high, high	6	0
E	<i>Pseudotsuga</i> m.	ENE	Shallow, coarse sandy loam	2250	Gentle slope ridge crest	.2313, high	24	10

rocky soils with northerly aspects; D is predominantly limber pine and is on a very steep, south-facing slope of loose talus.

During the final coring of site A, it was noted that some selective logging had taken place there, affecting the spacing of individual trees and potentially having a detrimental effect on the dendroclimatological value of ring series from this site. Cores from this locale were, therefore, not analyzed.

Coring technique. Standard 18 inch and 14 inch increment borers were used to remove at least two cores from each of 12 to 15 trees at each site. Cores were taken at breast height from opposite sides of the tree and perpendicular with the hill slope, and were encased in waxed paper straws on which all pertinent data were recorded. Records were also kept on various characteristics of each tree, including breast height diameter, approximate height, evidence of disease or damage, nearest competitors and micro-topographic location.

Processing. In the laboratory, dried cores were glued into wooden mounts, surfaced by cutting and sanding and subjected to preliminary screening. Those cores showing distinct growth abnormalities caused by disease or injury were removed from further analysis. The remainder were cross-dated by me and checked by Dr. L. B. Brubaker of the University of Washington College of Forest Resources.

Cores were given a second screening at this time, and those that failed to cross-date or that had more than one percent missing rings being eliminated. In the end, 28 cores remained. A technician then measured ring widths using a dendrochronometer and the resultant measurements were compiled on computer cards for standardization and analysis.

Standardization is the process by which ontogenetic changes in ring-width are removed by mathematically fitting a straight line, exponential or polynomial function to the raw ring-width data

(Fritts, 1974, 1976). The standardization of ring-width, or tree-ring index for each year is computed as one plus the difference between the actual ring-width and the width predicted by the growth function. Index values usually range from 0 for missing rings to 2.0 or more for unusually wide rings. In this instance standardization was achieved using the INDXA program developed for this purpose by L. N. Ray of the Laboratory for Tree Ring Research, University of Arizona, Tucson. The choice of which growth function to use in each case was based on observation of a ring-width graph for each core. In general, limber pine took a straight line function while an exponential was usually applicable to the Douglas fir.

The ten cores from Site B and nine from Site D, representing eleven trees, were first summarized into site chronologies then into a combined chronology for Douglas fir. The summary of nine cores from seven trees at Site D provides the total record for limber pine. Because the INDXA program could not calculate index summaries for series longer than 500 years, sites B and D were summarized by hand.

Analysis: Climatic response. Dendroclimatological analysis of the two tree-ring chronologies consisted of determining mathematically the relationship between ring index and various climatic variables, indentifying those variables with the highest correlation to ring-width indices and using these findings to ascertain the climatic meaning of temporal variations in those ring indices.

The climatic variables considered were September discharge of the Salmon River at Challis, at Salmon and the difference between the two readings, and monthly and mean-annual temperature and precipitation. Monthly data included June through December of the previous year and January through August of the growth year. Values of climatic variables were the means for all weather stations in the Northeastern Valleys climatic division (Climate of Idaho, U.S.

Weather Service). Precipitation data included the years 1895 - 1975 AD; temperature, 1914 - 1975, and river discharge, 1932 - 1958.

These 35 variables were compared against mean tree-ring indices for each species using the Pearson Product Moment correlation program provided by SPSS. Actual computer analysis was assisted by Stephen Hackenberger of Washington State University. The resultant bivariate correlations are presented in Table 69 with monthly correlations also summarized in graphic form (Figure 54). Graphs resemble response functions (Fritts et al., 1971) but are distinct in that the latter are calculated by step-wise multiple regression. The simple correlations presented here were developed to identify those climatic factors accounting for the greatest amount of variance in ring-width, rather than to fully understand physiological responses of the two tree species.

Considering the correlation matrix (Table 69, Figure 54), a strong correspondence is evident between the relationships of the two species to climate. Both show the highest positive correlations with river discharge (limber pine with discharge at Salmon, Douglas fir with the difference in discharge between two measurement sites), although limber pine (.7434) correlates most highly with the previous year's discharge. Next highest correlations are negative, and in both species ($lp = -.4235$, $Df = -.5899$) are with the previous year's July temperature. The only other noteworthy correlations, still fairly high, are again positive, this time with annual precipitation ($Df = .4358$) and June precipitation ($Df = .4049$, $lp = .3384$), both of the growth year.

These results show clearly that in both limber pine and Douglas fir growing at the lower tree line in the Doublespring Canyon, tree-ring index is a measure of moisture stress as manifest in the combined effects of spring precipitation (or precipitation in general, i.e., discharge) and high summer temperatures. Therefore, the tree-ring chronologies can be read as a history of moisture availability in the Pahsimeroi Valley. Narrow rings indicate low runoff,

low spring precipitation and/or hot summers; wide rings, the inverse.

Table 69. Pearson Correlation Coefficients (r) Comparing Tree-ring Indices for Limber Pine and Douglas Fir with 35 Climatic Variables from the Same and Previous Year¹

Same Year	Douglas fir	Limber pine
Salmon River Discharge		
Challis	.4954*	.4423*
Salmon	.5899*	.4821*
Salmon-Challis	.5784*	.4176*
Precipitation		
January	.3141	.2011
February	.0631	-.1554
March	-.1339	-.1422
April	.0906	.0842
May	.3010	.1155
June	.4049*	.3384*
July	.1303	.0376
August	.1219	-.1085
Total Annual	.4358*	.2025
Temperature		
January	-.0835	.0270
February	.0778	.1811
March	-.1572	-.0302
April	-.0521	-.1361
May	-.2591	-.2361
June	-.4651	-.1772
July	-.5395*	-.3219*
August	-.4540*	-.2752
Mean Annual	-.3283	-.1174

Table 69. (continued)

Previous Year	Douglas fir	Limber pine
Salmon River Discharge		
Challis	.5829	.4087*
Salmon	.7218*	.4567*
Salmon-Challis	.7434*	.4109*
Precipitation		
June	.2891	.2680
July	.1166	.1396
August	.0532	-.1810
September	-.0216	-.0778
October	.0055	.0496
November	.2180	.1911
December	.0749	-.0793
Total Annual	.3826*	.1135
Temperature		
June	-.4358*	-.2737
July	-.5899*	-.4235*
August	-.2874	-.1551
September	-.0349	.1075
October	-.0510	-.0700
November	-.0329	.1380
December	-.0595	.0405
Mean Annual	-.0852	.0196

¹Asterisks mark higher correlations.

Interpretation. Tree-ring chronologies are shown graphically, in two forms. Both species are shown in their entirety as graphs of 40 year mean index values (Figure 55), and to provide the detail necessary to interpret change during the Metallic Tradition, a graph of annual indices between 100 and +25 BP is also given (Figure 56). Note the general correspondence between the chronologies of the two

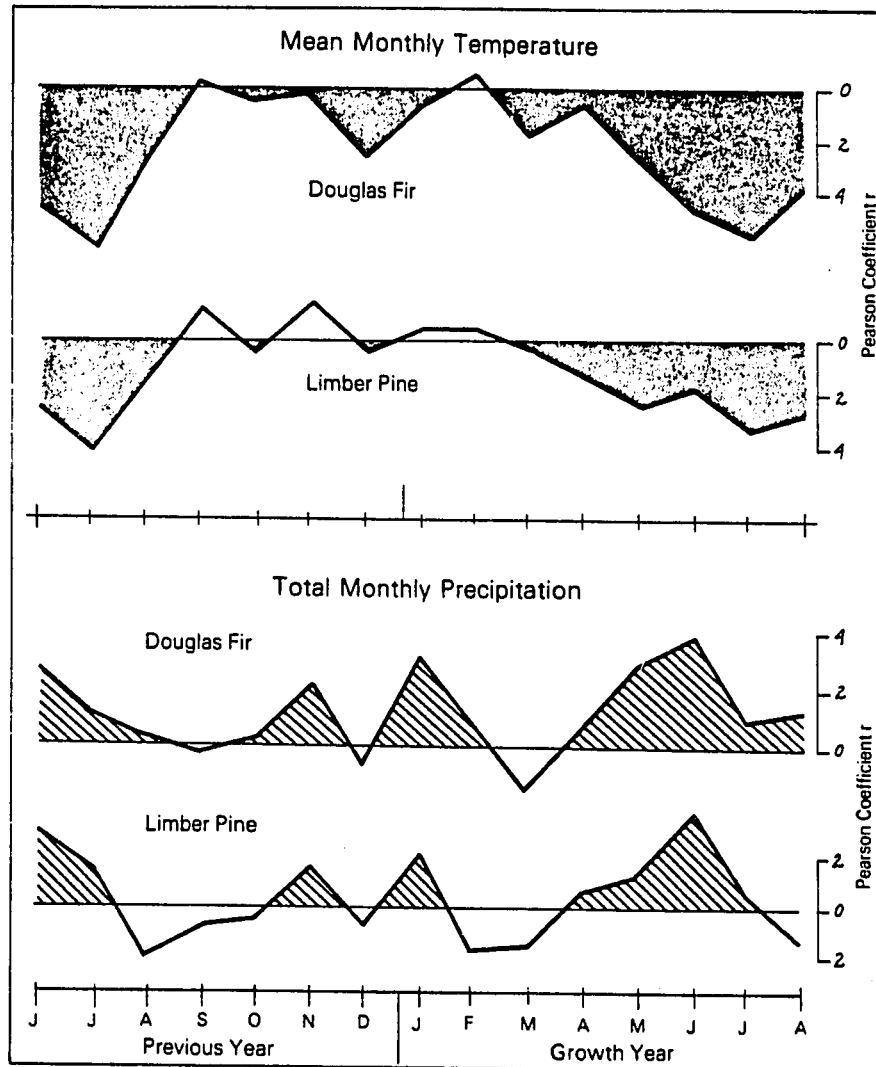


Figure 54. A graph of Pearson correlation coefficients, showing the relationship between tree-ring indices for limber pine and Douglas fir, and monthly weather conditions from June of the previous year.

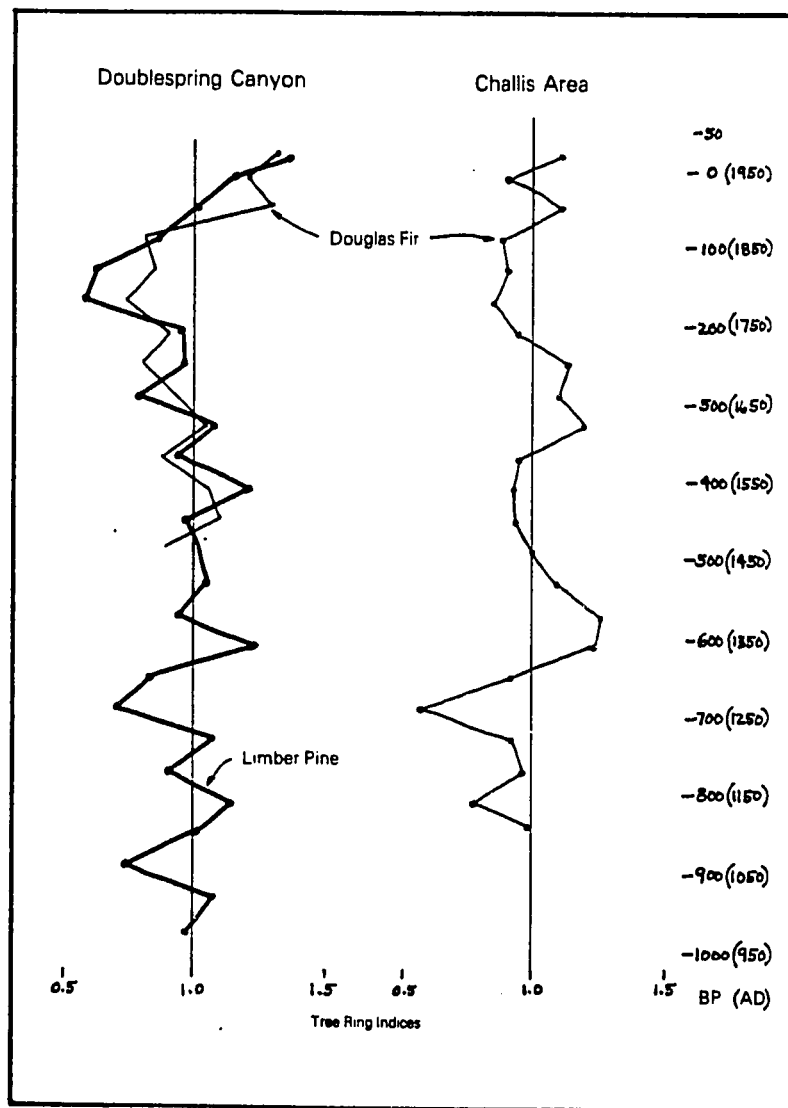


Figure 55. Summary Tree ring records from Doublespring Canyon shown with the Douglas fir chronology from the Challis vicinity from 1000 BP. Data are presented as 40 year means of ring width indices.

species, which might have been expected from their similar response patterns.

From 1013 to around 600 BP (Figure 55), indices fluctuate on a periodicity of less than 100 years between slightly moist and very dry, but the general picture of this interval, compared to the subsequent one, is of aridity. From 600 to between 350 and 300 BP (the two species differ here) conditions are consistently more moist, with rare dry periods of minor severity. By 250 BP a drying trend has begun, culminating around 100 - 150 BP. After 50 BP, moister conditions return. However, the last 75 years (Figure 56) are actually characterized by extreme variability. Wet weather prevails from 50 to 25 BP, followed by a severe drought lasting to after 10 BP. Thereafter conditions moderate, but are never again as wet as in the early twentieth century.

Hackenberger's findings are similar (Figure 55), as one would expect from the proximity of his tree-ring site. Dry conditions, showing less fluctuation in this record, persist from 850 to 650 BP, followed by wet to moderate conditions coming to an end between 350 and 250 BP. Aridity then prevails until the last century, where his findings and mine coincide closely. Both records also compare favorably with the findings of others, but show the major wet interval beginning around a century earlier than it does in eastern Washington (Davis et al., 1977).

Sagebrush, Grass and Climatic Change

The purpose of this chapter has been to determine whether changes in the proportions of sagebrush and grass in the Pahsimeroi Valley can be accounted for by coincident changes in climate.

In the foregoing pages I have compiled records of change in past patterns of precipitation and temperature and presented an outline of the conditions under which grass or sagebrush would be favored in a competitive relationship between forage types. Sagebrush reproduction and growth are promoted, at the expense of grass, when a warm, dry climate prevails and grass competes best under

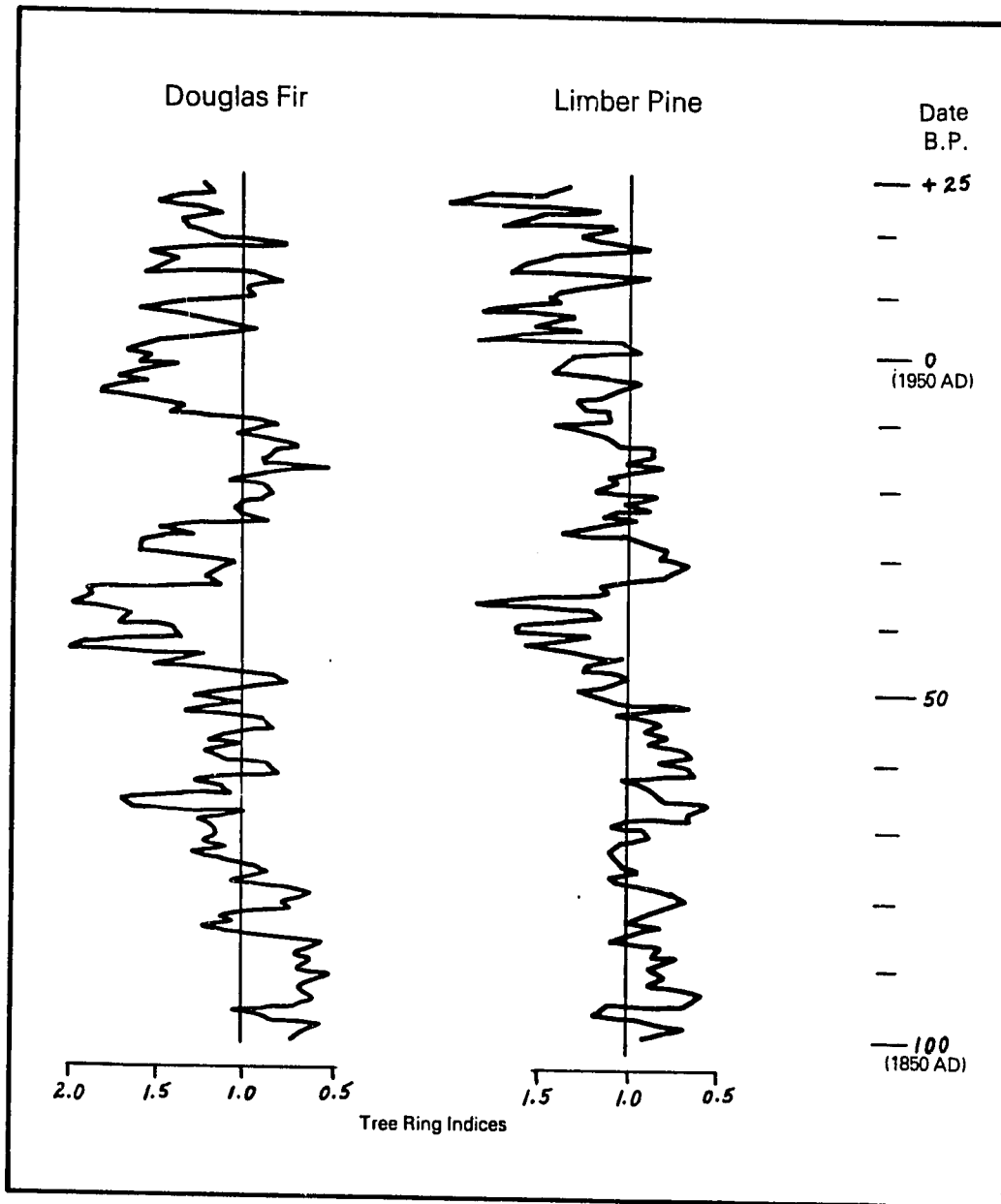


Figure 56. Annual mean tree ring indices for Doublespring Canyon Douglas fir and limber pine, for the period 100 BP (1850 AD) to +25 BP (1975 AD). Note generally low growth prior to 50 BP and between 10 and 25 BP in both species.

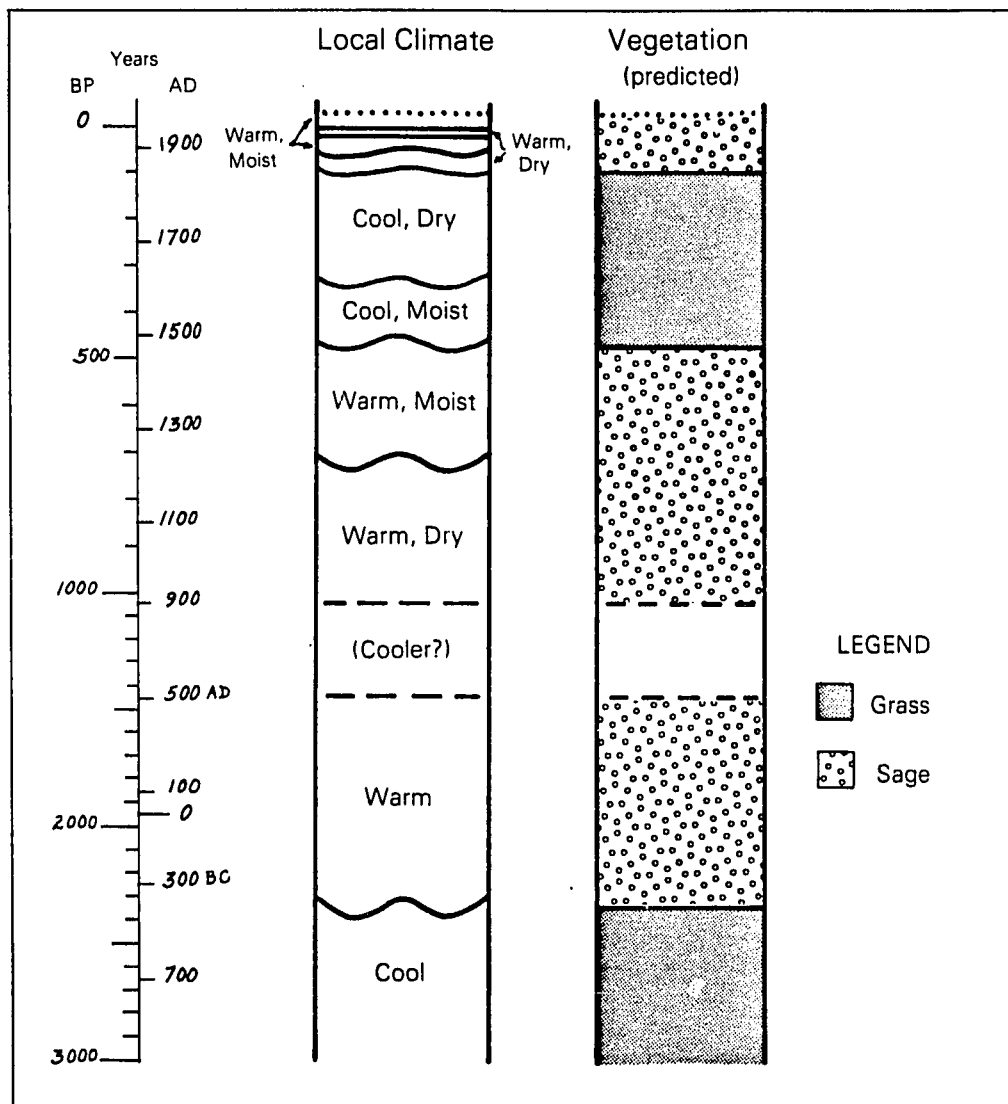


Figure 57. History of the Pahsimeroi Valley climate, showing the competitive relationship between sagebrush and grasses as predicted from temperature and moisture data. The left column summarizes climatic conditions, the right presents the plant taxon which would have had competitive advantage under those conditions. Neutral indicates that the previously favored plant would maintain its advantage, but show no proportional increase relative to its competitor. Note the variable time scale.

cool, moist conditions. Figure 57 combines temperature and precipitation records into a summary history of Pahsimeroi Valley climate and identifies those time periods when one or the other forage type would have had competitive advantage. These records can be compared against the pollen ratio and concentration graphs in Figure 49.

The climatic record is incomplete prior to 1000 BP, with data available only for temperature. We can therefore only speculate as to the favored forage types. During the cold of the Temple Lake glaciation (3000 - 2400 BP) if moister conditions prevailed, grass may have had a competitive edge. Subsequent warming would favor sagebrush, if drier than the preceding era, but again no firm conclusion can be drawn until after 1000 BP. Then, certainly the 300 plus years of warm, dry climate could have promoted sagebrush populations, which would persist in the moister but still warm period that followed.

Not until around 500 BP did conditions develop that would have given grasses the competitive advantage. These cold, moist years lasted until around 300 BP, after which dry but cold (neutral) weather would have maintained the status quo. Poor times for grass followed after about 100 BP (125 years ago) when warming temperatures of the late 19th century intersected with drought to create the warm-dry sagebrush climate. There was then a brief resurgence of wet weather which probably stabilized the changing ecosystem briefly, then the drought of 10 - 25 BP (the 1930's) would have finally tipped the competitive balance in favor of sagebrush, which continues to dominate the moist, warm present.

Changes in the sage-grass balance indicated by the ratio between the pollen of the two plant types (Figure 49) correspond almost exactly with those predicted from the climatic record. This is also true for the pollen concentration data, wherein the sharp surge in Artemisia pollen takes place by 600 BP (warm, moist) but no major increase in grass pollen concentration occurs until after 500 BP, when cold, moist conditions finally prevail. Therefore, the climatic hypothesis is the better one: vegetation changes in the

first and fifth centuries BP can be explained by climatic variation.
The cultural hypothesis is discarded.

CHAPTER TWELVE

Summary and Conclusion

Two trends in American archaeology are rapidly converging into an approach I have called evolutionary human paleoecology. With a foundation of ecological theory and Darwinian evolutionism, and constructed of variables directly observable in the archaeological record, such an approach may give archaeology the capability for understanding the processes of cultural evolution. In fact, as the paleoscience with the most complete record, archaeology may ultimately contribute to the evaluation of existing tenets of evolutionary theory and to the development of a comprehensive theory of evolution in self-replicating mechanisms. I have suggested here that if our discipline is to approach these lofty goals, we must develop the ability to study the influence of natural selection on individual episodes of change. Toward this end I have introduced a method for investigating the evolutionary relationship between human adaptation and climatic change. A systematic, decision-making model, that method sequentially employs data on adaptive patterning (the "fossil" of adaptive behavior), ecological niche, effective environment and the biophysical environment as a whole to test six alternative hypotheses. These hypotheses address whether an observed change in the archaeological record is actually the result of natural selection, and if so, whether the shift in selection pressures leading to the change is exerted by change generated internally through the spontaneous development of new, more adapted variants (Mode 1) or externally by a changed environment acting on pre-existing variation (Mode 2). If change occurs in Mode 2, further hypotheses posit the proximate cause for environmental change.

The method has been applied to a study of changing adaptive patterns, specifically land use and settlement patterns in the

Pahsimeroi Valley, Idaho. Concentrating on the Upper Valley, a high, cool, semi-arid steppe of steep-walled canyons and broad alluvial plains, the Pahsimeroi Valley Study collected and analyzed four sets of data: adaptive patterning, human niche, effective environment, and paleoclimate.

First, I identified a history of settlement and land use from 8000 BP to the present day, collecting archaeological data by intensive survey of a multilevel stratified sample, then defining functional classes of discrete artifacts and occupations, placing each in chronological order and observing the temporal distribution of variable forms of settlement and land use. The result revealed ten distinguishable time periods, six in the Lithic Tradition (Native American prehistoric/protohistoric) and four in the Metallic Tradition (Modern Euro-American) and showed numerous episodes of change. The method was then followed to analyze two of these episodes. Niche data were obtained by excavation and surface collection at archaeological sites; bones from the modern land surface and a non-archaeological cave deposit and pollen from a small pond provided information on effective environments; and a 1,000 year paleoclimatic paleotemperature and by dendroclimatological analysis of the ring patterns of local trees. Whenever possible all data were acquired in the Project Area. In no case were historic records used, and all data were analyzed by accepted archaeological and paleoecological procedures, regardless of age.

The data are far from perfect, primarily due to small sample sizes. This is especially true of niche data and the paleontological collection used to study the history of local ungulate populations. For this reason, the conclusions I present below are substantially compromised; they are the best conclusions reachable on the basis of minimal data. Further, more substantial studies in the same region are, therefore, needed to test the statements I make here. However, my purpose has not been to argue for or against specific causes of adaptive change in Central Idaho. Rather I have sought to demonstrate the feasibility of a method sensitive to evolutionary and ecological theory.

The two episodes of change I chose to study occurred at around 400 BP in the Lithic Tradition (Prehistoric Period) and between 0 and 20 BP in the Metallic (Historic Euro-America). In the first instance, hunting patterns show an abrupt change at the same time the size of domestic settlements and, presumably, the size of human groups visiting the area declines markedly. A shift from pastoralism and permanent habitation toward hunting and temporary habitation is evident in the second case. I present a synopsis of each event below, first describing the nature of the archaeological change, and then presenting a scenario of cause and effect, beginning with climate. The data on which each synopsis is based are presented in Figures 58 and 59.

Pronghorn to Bison: The 400 BP Change Between
Lithic Tradition Periods 5 and 6

Before 400 BP, and for roughly 1400 years previous, people had visited the Upper Pahsimeroi Valley seasonally, in the spring to harvest pronghorn, bighorn sheep and a few mountain bison. Most of them came in groups, probably several families at a time in camps averaging 850 square meters in area. They hunted along streams in brushy habitats of canyon bottom and canyon mouth with projectiles having small, narrow-necked points and in the open plain along river and terraces with larger projectiles with broad-necked tips. Their mode of hunting may have included communal drives, hence the large groups. A few people, however, came in small groups and camped in the canyons.

Shortly after 500 BP, the climate changed (Figure 58). Warm-dry and warm-moist weather was replaced by cool-moist, then cool-dry. Sagebrush, favored by warm, especially warm-dry conditions, lost its competitive advantage and the steppe grasses thus became more abundant and productive. This sharp rise in grass, indicated in the pollen profile of Bisonsweh Pond, occurred shortly after 480 BP, and had a noticeable impact on ungulate populations. Although mountain sheep remained stable, relative numbers of bison, a grazer,

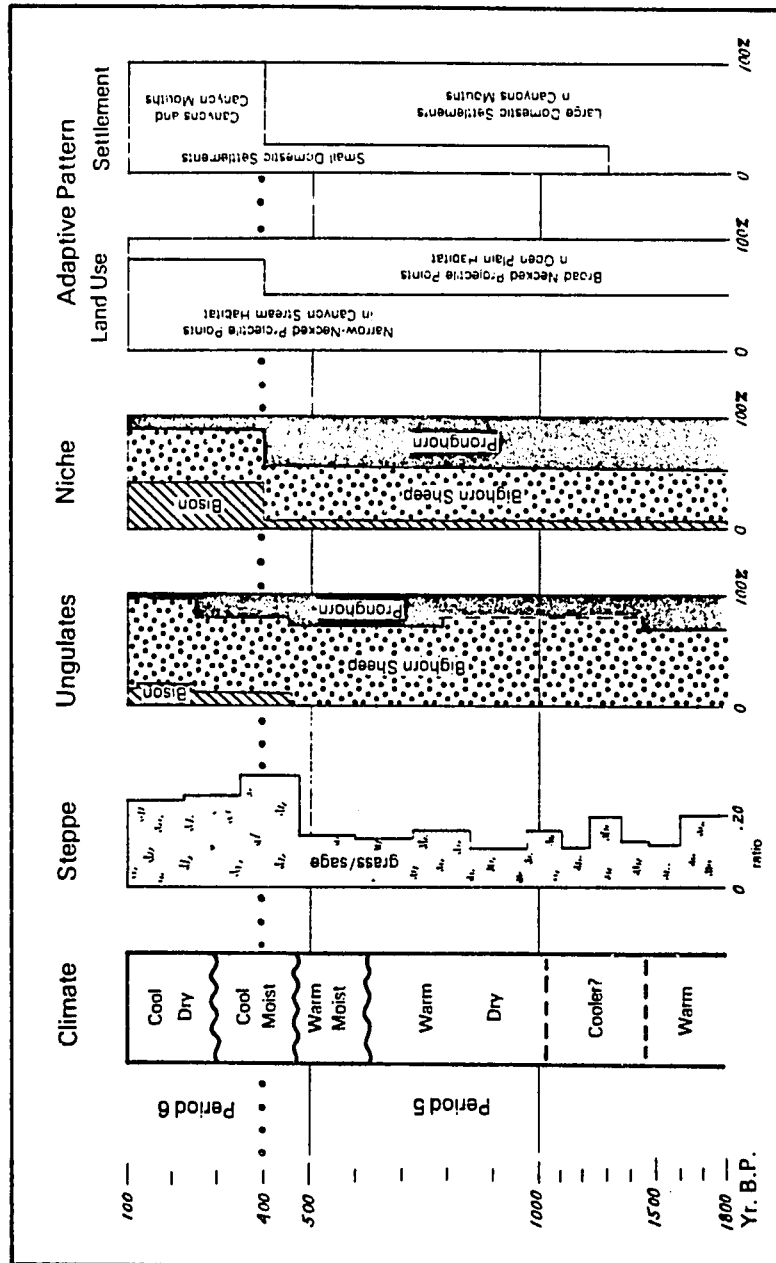


Figure 58. Summary of information on causes for change in adaptive patterns between Periods 5 and 6.

increased and pronghorn, consumer of sagebrush, declined. This change, from the gregarious, easily driven, open-living pronghorn to the more solitary mountain bison, denizen of brushy stream banks, exerted a selection pressure on patterns of adaptive behavior. The small groups who visited canyons before 400 BP became more fit and, moving into the canyon-mouth habitat, entirely replaced more populous camps. Communal (presumably) hunting in the open plain for pronghorn declined markedly with the reduction in this species' relative availability and nearly all predatory activity took place along brushy canyon-stream habitats with small, narrow-necked projectile points. The Bison, a nearly solitary, water consuming animal with poor eyesight, was now a quarry nearly equal in importance to mountain sheep.

This event is a change of Mode 2 type. It is evident that the variability in technology and settlement size acted on by altered pressures of selection - the change in availability of species with distinct habitats and patterns of behavior - already existed before the change in adaptive patterns occurred. Climate is identified as the phenomenon that, through altering floral, thence faunal environments, precipitated the change in human adaptive behavior.

Hunting Replaces Pastoralism: Metallic Tradition, 20 to 0 BP

At around 80 BP (1879 AD) the native, Lithic Tradition was entirely replaced by a distinct adaptation using metal tools and relying on pastoralism of ungulates - cattle, horses and sheep. The settlement pattern had two forms; permanent building and corral complexes and large, temporary campsites. Both were situated in the canyon mouths or along rivers and streams of the open plain. By 38 BP a new form of settlement, the small hunting camp, appeared and gradually, along with a hunting-dominated pattern of land use, replaced its predecessor. Climatic events played an important role in this transposition, as they had at 400 BP.

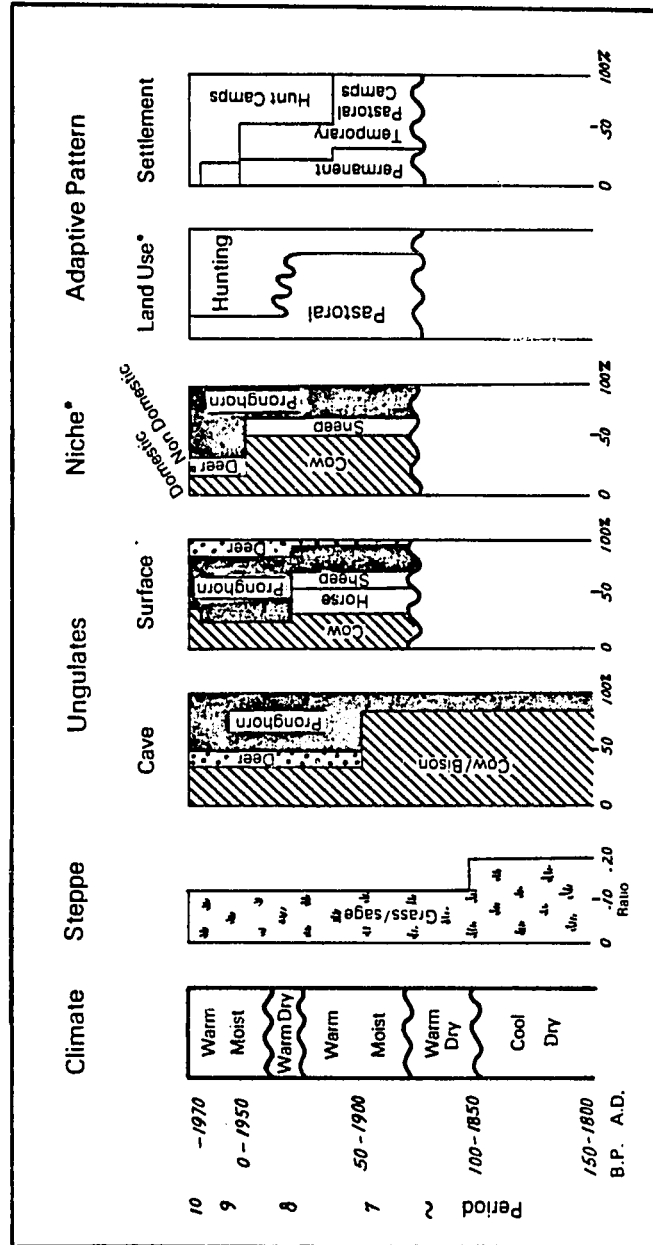


Figure 59. Summary of information on causes for change in Metallic Tradition adaptive patterns.

The cool, dry interval that prevailed at the close of Lithic Tradition Period 6 ended around 100 BP (1850) (Figure 59). The weather became warmer and alternately dry and moist for the next 125 years. Warming, dry conditions of 100 - 70 BP began to erode the competitive advantage of grass in the local steppe, but the forty-odd years of wetter weather that followed temporarily stayed the loss of grass. It was during the onset of this moist interval that Metallic Tradition occupation began in the Pahsimeroi Valley, and old timers invariably recall the better pasturage. Harsh droughts began again in the late third decade BP (late 1920's), administering a second blow to the grass cover and establishing a sagebrush dominance that prevails today. Pollen records from this period (Figure 59), showing vegetation history in 123-year-long segments, do not show such a precise progression of events, but demonstrate the demise of grass after 100 BP.

Deteriorating grass cover and enhanced sagebrush populations (speaking now in relative terms) affected wild and domestic ungulate faunas, favoring the sagebrush-eating pronghorn and the catholic browser, muledeer, over domestic grazers. Proportions of cattle to pronghorn had declined by 20 BP; horse and domestic sheep had effectively disappeared. Over all, a wild fauna, dominated by pronghorn, regained the sovereignty they had lost when the Metallic Tradition introduced livestock. Impact of this change on human habitation was severe. The resource niche, including primarily cattle, some sheep and a few wild browsers, rapidly gave way to pronghorn, reflecting a change in the selective advantage and therefore, the fitness of the pastoral adaptation. Permanent settlements were almost all abandoned in the Upper Pahsimeroi Valley and by +20 BP (1970), shortly before I began this study, seasonal pasturage of a few cattle and one struggling ranch operation (not sampled) were the last vestiges of pastoralism in this high, semi-arid habitat. Pronghorn thrive there today, numbering in the thousands and their predators - coyote, eagle and human - seasonally exploit this abundance. Pastoralism remains a way of life in lower

elevations and permanent settlements still exist there, but almost no one visits the Upper Valley, except to hunt (or fish).

As before, when wetter conditions brought bison, bison hunting techniques and small settlements to the fore, warming, drying, climate returned the Project Area to aridity, selecting for a human adaptation more in tune with the sagebrush steppe. Again, this evolutionary change is evident in the gradual replacement of one adaptive pattern by another and change appears to be of the Mode 2, environmental selection type.

Conclusion

In the foregoing I have shown how we might use a method based on evolutionary human paleoecology to investigate the process of evolution in individual instances of change. Such a capability is essential if archaeologists are ever to apply Darwinian evolutionary theory to an understanding of cultural process. The method I have presented concentrates on how we should proceed to explicate the role of climate in cultural evolution, but with additions, might be applied to any form of evolutionary event.

I do not presume to have made discoveries through the Pahsimeroi Valley Study that might be used to generate universal principles of culture process. The results are simply achieved through the application of existing theory and my conclusions about the events in question are the best hypotheses, given current data about the circumstances of those events and them alone. What I have shown is that evolutionary human paleoecology and the method that is its entailment are useful means for studying change in the archaeological record.

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Thomas, D. H.

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1971a Prehistoric subsistence-settlement patterns of the Reese River Valley, central Nevada. Ph.D. dissertation, University of California, Davis.

1971b On distinguishing natural from cultural bone in archaeological sites. American Antiquity 36:366-371.

1973 An empirical test for Steward's model of Great Basin settlement patterns. American Antiquity 38:155-177.

1975 Nonsite sampling in archaeology: up the creek without a site? In Sampling in archaeology, edited by J. Mueller, pp. 61-81. University of Arizona Press, Tucson.

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1978a Arrowheads and atlatl darts: how the stones got the shaft. American Antiquity 43:461-472.

1978b The awful truth about statistics in archaeology. American Antiquity 43:231-244.

1981 God's truth in Great Basin archaeology? American Antiquity 46:644-648.

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1978 Prehistoric settlement changes in the southern Northwest Coast: a functional approach. Reports in Archaeology No. 5. University of Washington, Department of Anthropology, Seattle.

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Tomanek, G. W.

1959 Effects of climate and grazing on mixed prairie. In Grasslands, edited by H. B. Sprague, pp. 371-377. American Association for the Advancement of Science Publication No. 53.

Trigger, B. G.

1967 The determinants of settlement patterns. In Settlement, society and archaeology, edited by K. C. Chang. National Press, Palo Alto.

1967b Settlement archaeology, its goals and promise. American Antiquity 32:149-160.

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1974 Experimentation in the formation of edge damage: a new approach to lithic analysis. Journal of Field Archaeology 1:171-196.
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1979 Regarding fracture initiations. In Lithic Use Wear Analysis, edited by B. Hayden. Academic Press, New York.
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1969 Taphonomy and population dynamics of an early Pliocene vertebrate fauna, Knox County, Nebraska. University of Wyoming Contributions in Geology Special Papers 1:1-69.

1981 Ancient ashfall creates Pompeii of prehistoric animals. National Geographic 159:66-75.

Waddington, J. C. B.

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Walker, D. E.

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Watson, P. J., S. A. LeBlanc and C. L. Redman

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1972 Late postglacial climatic change in the northern midwest, U.S.A.: quantitative estimates derived from fossil pollen spectra by multivariate statistical analysis. Quaternary Research 2:70-115.

Webb, T. III, R. A. Laseski and J. C. Bernabo

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Webb, T. III and J. H. McAndrews

1975 Corresponding patterns of contemporary pollen and vegetation in central North America. Geological Society of American Memoir 145.

Wendland, W. M. and R. A. Bryson

1974 Dating climatic episodes of the Holocene. Quaternary Research 4:9-24.

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1953 Prehistoric settlement patterns in the Viru Valley, Peru. Bureau of American Ethnology, Bulletin 155. Washington D.C.
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1956 Prehistoric settlement patterns in the New World. Viking Fund Publications in Anthropology 23.
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1958 Method and theory in American Archaeology. University of Chicago Press, Chicago.
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1976 The process of farming diffusion in the southwest and Great Basin. American Antiquity 41:421-429.
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1969 The Riverton Culture. Illinois State Museum, Reports of Investigations, No. 13. Springfield.
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1973 Hydrodynamic sorting and ecology of pleistocene mammalian assemblage from California. Paleogeography, Paleoclimatology, Paleoecology 13:91-101.
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1976 Prehistoric hunting of New World wild sheep: implications for the study of sheep domestication. In Cultural change and continuity: essays in honor of James B. Griffin, edited by C. Cleland, pp. 293-318. Academic Press, New York.
- Wright, G. A., S. Bender and S. Reeve
1980 High country adaptations. Plains Anthropologist 25:181-269.
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1964 The cultural sequence of the Packard Site, Moyes County, Oklahoma. Archaeological Site Report, No. 2. Oklahoma River Basin Survey Project, University of Oklahoma Research Institute, Norman.
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1975 Tool microwear and functional types from Hogup Cave, Utah. Tebiwa 17:2:1-32.
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Young, S. P. and H. H. T. Jackson

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Ziegler, A. C.

- 1973 Inference from prehistoric faunal remains. Addison-Wesley Module in Anthropology 43.

Zohary, D.

- 1969 The progenitors of wheat and barley in relation to domestication and agricultural dispersal in the Old World. In The domestication of plants and animals, edited by P. Ucko and G. Dimbleby, pp. 47-66. Duckworth, London.

Zubrow, E. B. W.

- 1975 Prehistoric carrying capacity: a model. Cummings, Menlo Park.

CURRICULUM VITAE

NAME: James C. Chatters

ADDRESS: Department of Anthropology and Museum of Man
Central Washington University
Ellensburg, Washington 98926

BIRTHDATE: March 20, 1949

MARITAL STATUS: Married, two children

EDUCATION: Ph.D., University of Washington, December, 1982.
M.A., University of Washington, December, 1975.
B.A., with distinction, Washington State University,
February, 1971.
University of New Mexico, 1969-1970.

FELLOWSHIPS AND HONORS:

National Science Foundation Graduate Fellowship, 1971.
(which I declined)

Woodrow Wilson Fellowship Finalist, 1971.

Phi Beta Kappa

Phi Kappa Phi

PROFESSIONAL EMPLOYMENT:

Assistant Director, Central Washington Archaeological
Survey, Central Washington University, Ellensburg,
Washington, June 1982 - Current.

Assistant Professor, Department of Anthropology
Central Washington University, Ellensburg, Washington,
September 1980 - June 1981. Currently Adjunct
Assistant Professor.

Acting Director, Office of Public Archaeology, Univer-
sity of Washington, Seattle, Washington; May 1978 -
January 1980. Research Scientist, March 1978 -
September 1980.

Archaeological Consultant, Jack McCormick & Associates,
Berwyn, Pennsylvania and WAPORA, Inc., Chicago,
December 1977 - July 1978.

Zone Archaeologist, East Zone, Custer NF. Watford City, N.D., July - November, 1977.

Predoctoral Teaching Associate, Department of Anthropology, University of Washington, Seattle, Washington, 1975 - 1976.

Teaching Assistant, Department of Anthropology, University of Washington, Seattle, Washington, 1973 - 1975.

Assistant Highways Archaeologist for Western Washington, University of Washington, Seattle, Washington, August - September, 1974.

Laboratory Assistant, Faunal Analysis Laboratory, Department of Anthropology, University of Washington, Seattle, Washington, June - October 1973.

Research Associate, Aleutian Ecosystems Project, Department of Biobehavioral Sciences, University of Connecticut, Storrs, Connecticut, 1971 - 1972.

GRANTS AND CONTRACT AWARDS:

Graduate Student Travel Grant, Department of Anthropology, University of Washington, 1975 - 1976. (\$400).

National Science Foundation Doctoral Dissertation Grant, "The Pahsimeroi Valley Longitudinal Land Use Study" Grant No. SOC75-16886, 1975 - 1976. (\$7,900).

Graduate School Research Grant, University of Washington Graduate School, 1976 - 1977. (\$600).

Survey and Evaluation of Cultural Resources along Crab Creek and Dry Coulee Channel, Grant County, Washington. Contract between University of Washington and U.S. Bureau of Reclamation. Principal Investigator with R.C. Dunnell and J.V. Jermann, 1978. (\$12,000).

Exploratory Excavations at Wa-pai-xie Cave and Rock-shelter, Kittitas County, Washington. Contract between University of Washington and the Department of the Army, Fort Lewis. Principal Investigator with R.C. Dunnell, 1978. (\$2,000).

Cultural Resources Inventory of Land Exchange tracts in Mount Baker-Snoqualmie National Forest. Contract between University of Washington and the U.S. Department of Agriculture, Forest Service. Principal Investigator with R.C. Dunnell, 1978. (\$5,000).

Cultural Resource Reconnaissance Survey of the Northern Tier Pipeline Route. Contract between University of Washington and Environmental Research and Technology (Cambridge, Massachusetts). Principal Investigator, 1978. (\$7,000).

Archaeological Survey and Test Excavations in Carty Unit, Ridgefield National Wildlife Refuge. Contract between the University of Washington and the U.S. Fish and Wildlife Service. Principal Investigator with R.C. Dunnell and J.V. Jermann, 1979. (\$12,000).

Cultural Resources Inventory of the Murray Pacific and Champion International Land Exchanges. Contract between the University of Washington and the U.S.D.A., Gifford Pinchot National Forest. Principal Investigator with R.C. Dunnell and J.V. Jermann, 1979. (\$12,000).

Forest Management Cultural Resource Reconnaissance: Fort Lewis and Camp Bonneville. Contract between the University of Washington and the U.S. Army Corps of Engineers, Seattle District. Principal Investigator with R.C. Dunnell and J.V. Jermann, 1979 - 1980. (\$12,000).

Excavations at the Sba'badid Site, 45KI51. Contract between the University of Washington and CHG International. Principal Investigator with R.C. Dunnell and J.V. Jermann, 1979 - 1980. (\$49,950).

Survey and Evaluation of Selected Tracts in the Columbia Basin Project. Contract between the University of Washington and the U.S. Bureau of Reclamation. Principal Investigator with R.C. Dunnell and J.V. Jermann, 1978 - 1980. (\$119,000).

Earlington Excavations. Contract between the University of Washington and First City Equities. Principal Investigator with R.C. Dunnell and J.V. Jermann, 1980 - 1981. (\$43,000).

Archaeological Inventory and Test Excavations on the Quadrant Development, Personal contract with Quadrant, Inc., Bellevue, Washington, 1981. (\$3,200).

Plus numerous small (less than \$2,000) contracts from private and public agencies.

Chief Joseph Dam Cultural Resources Testing, Belvedere (RM590) Area. Contract between Central Washington University and the USACE. Principal Investigator. June 1982 - August 1983. (\$240,000).

ARCHAEOLOGICAL FIELDWORK:

Full Scale Archaeological Excavations of the Sba'badid and Earlington Sites 45KI51 and 45KI59, King County Washington. University of Washington/CHG International and First City Equities 1979 and 1980. Principal Investigator and Director.

Cultural Resources Survey of 68,000 Acres of Columbia Basin Project. Grant, Franklin and Adams Counties, Washington. University of Washington/U.S. Bureau of Reclamation. April - September 1979. Principal Investigator and Director.

Exploratory Excavations of Wa-pai-xie Rockshelter and Cave, 45KT241, Kittitas County, Washington. University of Washington/Department of the Army. August - September, 1978. Principal Investigator and Director.

Cultural Resource Survey of Crab Creek and Dry Coulee, Grant County, Washington. University of Washington/U.S. Bureau of Reclamation. July - September, 1978. Principal Investigator and Director.

Test and full scale Excavations of Sites 45SN48 and 45SN49, Snohomish County, Washington. University of Washington/Washington Department of Transportation. 1978, 1980. Principal Investigator.

Cultural Resource Overview of Olympic National Forest, Western Washington. Jack McCormick & Associates/U.S. Forest Service. December 1977 - February, 1978. Archaeological Consultant.

Pahsimeroi Valley Longitudinal Land Use Study; Phases I & II. Central Idaho. Ph.D. dissertation research, NSF/University of Washington. 1974 - 1975. Project Director.

Archaeological Survey of the Vancouver Lake - Lake River Area. Southwest Washington. USACE/University of Washington. R.C. Dunnell, Director. December 1972 - January 1973. Assistant Director.

Schultz Marsh Site (45CL29) Excavations. Southwest Washington. Washington State Highways/University of Washington. D. Munsell, Director. July 1972. Tactician and Field Assistant.

Kersting Site (45CL21) Excavations. Southwest Washington. Washington State Highways/University of Washington. June - September 1972. Senior Archaeological Laborer.

Annual participation in numerous surveys and excavations of prehistoric sites in Washington, Idaho and Saskatchewan and Hawaii, 1961 - 1970. Plus various small-scale survey and testing projects 1977 - 1981.

OTHER PROFESSIONAL EXPERIENCE:

Analysis of Fauna, Pollen and Tree-ring data from the Pahsimeroi Valley, Idaho. Dissertation research. 1976 - 1981.

Analysis of fauna from various sites in Washington, Idaho and Alaska, dating from 8000 years BP. On a contractual basis, and in my capacity as Research Associate, University of Connecticut and Research Scientist, University of Washington.

Obsidian Hydration Analysis for D.H. Thomas, American Museum of Natural History, New York, N.Y. Spring 1974.

PUBLICATIONS:

- 1966 Knife found near Edam Saskatchewan, implications. Saskatchewan Archaeology Newsletter. September, 1966. Saskatchewan Archaeological Society, Regina.
- 1969 A settlement pattern in the foothills of east central Idaho. Tebiwa 12:31-38. Junior author with E.H. Swanson and C. King.
- 1976 The Pahsimeroi Valley longitudinal land use study. Archaeological Reports No. 4. U.S. Forest Service, Ogden, Utah.
- 1979 Survey and Evaluation of Cultural Resources along Crab Creek and Dry Coulee, Grant County, Washington. University of Washington, Office of Public Archaeology, Reconnaissance Report No. 22.
- Exploratory Excavations at the Wa-pai-xie Archaeological Site Complex (45KT241). University of Washington, Office of Public Archaeology, Reconnaissance Report No. 23.

- Test Excavations: 45SN29, 45SN48 and 45SN49, Snohomish County, Washington. Reports in Highway Archaeology No. 4. Office of Public Archaeology, University of Washington. James C. Chatters and Gail S. Thompson.
- 1980 Cultural Resources of the Columbia Basin Project: An Inventory of Selected Parcels. University of Washington, Office of Public Archaeology. Reconnaissance Report No. 32.
- 1981 Excavations at 45SN48N and 45SN49A, Snohomish County, Washington. University of Washington, Office of Public Archaeology, Reports in Highway Archaeology, No. 6. M.L. Stilson and J.C. Chatters.
- 1982 Prehistoric settlement and land use in the dry Columbia Basin. Northwest Anthropological Research Notes, Spring 1982.
- in preparation Archaeology of the Black River Duwamish Indians: History and Prehistory of Seattle's Original Inhabitants (suggested title). To be published as: University of Washington Reports in Archaeology No. 7 (for the layman).
- in preparation Evolutionary human paleoecology. In preparation for Advances in Archaeological Method and Theory, Vol. 7, Edited by M.B. Schiffer. James C. Chatters and Stephen Hackenberger.

REPORTS AND MANUSCRIPTS:

- 1969 An archaeological survey of the Ahupua'a of Lapakahi: feature typology and settlement patterns analysis. Department of Anthropology, University of Hawaii, Honolulu. Manuscript.
- 1972 Faunal analysis of sites MK2 and MK4, Nunivak Island, Alaska. Report to Michael Nowak, Colorado College, Colorado Springs. Xerox.
- 1973 Archaeological survey of the Vancouver Lake - Lake River Area, Clark County, Washington. Department of the Army, Corps of Engineers, Portland District, Portland, Oregon. R.C. Dunnell, J.C. Chatters, L.V. Salo. Xerox.
- 1974 Interim report on archaeological excavations at the Schultz Marsh Site. Report to the Washington State Department of Highways. Xerox.

- 1975 Analysis of artifacts from the Schultz Marsh Site, 45CL29, Clark County, Washington. M.A. research paper. Department of Anthropology, University of Washington. Xerox on file.
- 1977 The Pahsimeroi Valley Longitudinal Land Use Study. Phase II. Preliminary report to the United States Departments of Agriculture and the Interior. 70 pp., Xerox.
- 1980 Cultural Reconnaissance of Selected Portions of Fort Lewis, Pierce County, Washington. Office of Public Archaeology, University of Washington.
- 1981 Archaeology of the Sba'badid Site, 45KI51, King County, Washington. Office of Public Archaeology, University of Washington.

CONFERENCE PAPERS PRESENTED:

- 1972 The effect of early Russian contact on the Aleut population. Invited paper presented at the Recent Aleutian Fieldwork Symposium, 37th Annual Meeting of the Society for American Archaeology. Bal Harbor. May 1972.
- 1974 The relationship between pinon and California and Nevada Shoshonean population size. Paper presented at the 14th Annual Great Basin Anthropological Conference, Carson City, September 1974.
- 1976 The Schultz Marsh Site: a multi-component seasonal round occupation of the Lower Columbia River uplands. Paper presented at the 29th Annual Northwest Anthropological Conference, Ellensburg, April 1976.
- 1976 The definition of artifact and the distinction of cultural from noncultural bone in archaeological contexts. Invited paper presented at the Faunal Analysis Symposium, 29th Annual Northwest Anthropological Conference, Ellensburg, April 1976.
- 1976 A method for the study of dynamic, culture-environment interaction. Paper presented at the 41st Annual Meeting of the Society for American Archaeology, St. Louis, May 1976.
- 1978 An approach to the study of historic and prehistoric cultural ecology: an example from central Idaho. Invited paper presented in the Ethnobiology Symposium, 31st Annual Northwest Anthropological Conference, Pullman, April 1978.

- 1980 On the utility of paleontological and palynological data for the reconstruction of paleoclimate. Invited paper presented at the 33rd Annual Northwest Anthropological Conference, Bellingham, March 1980.
- 1980 Settlement and Land Use Patterns in the Dry Columbia Basin. Invited paper presented at the Plateau Archaeology symposium at the 33rd Annual Northwest Anthropological Conference, Bellingham, March 1980.
- 1980 Excavations at the Sba'badid Site (45KI51) King County, Washington. Research report presented at the 33rd Annual Northwest Anthropological Conference, Bellingham, March 1980.
- 1981 The application of coring techniques in inventory, assessment and the formulation of excavation strategy. Paper presented at the Annual Meeting of the Society for American Archaeology, San Diego, April 1981.
- 1981 Rise of the arrow: an evolutionary perspective on the replacement of atlatl and dart by bow and arrow. Paper presented at the 9th Annual Meeting of the Idaho Archaeological Society, Moscow, October 1981.
- 1982 Archaeology of the Black River Duwamish: an introduction to sites 45KI51 and 45KI59. Paper presented at the 35th Northwest Anthropological Conference, Burnaby, B.C., Canada, April 1982.
- 1982 Systemic change during the contact period in the Lower Duwamish Basin. Paper presented at the 35th Northwest Anthropological Conference, Burnaby, B.C., Canada, April 1982.

AUDIOVISUAL PRODUCTIONS:

- 1977 The Cutting Edge. Film strip on stone tool technology for use in middle school anthropology curriculum. Pacific Science Center, Inc., Seattle, Washington. Accepted into Washington State Middle School curriculum P.A.S.T., 1979.

TEACHING EXPERIENCE:

Courses taught* or prepared to teach (including dates):

Introduction to Archaeology* (1976, 1980-81)
 Archaeology of North America
 Archaeology of the Northwest* (1981)
 Cultural Resource Management
 Early Man in the New World

Archaeological Method and Theory* (1980)
 Archaeological Field Methods* (1974, 1981)
 Analysis of Artifacts* (1973)
 Faunal Analysis* (1976)
 Environmental Archaeology* (1981)
 Primitive Technology* (1980)

Courses Assisted:

Advanced Artifact Analysis (1974)
 Introduction to Archaeology (1973 - 1974)
 Museology (1975)
 Analysis of Artifacts (1975)

Training Workshops in Cultural Resource Management:

Custer National Forest Cultural Resource Management
 Workshop, Watford City, North Dakota. October 1977.

Fort Lewis Cultural Resource Technical Training Course,
 Fort Lewis, Washington. May 1978.

Gifford Pinchot National Forest Cultural Resource
 Technician Training Course, Packwood, Washington.
 September 1978.

Courses Taught, Division of Noncredit Studies, University of
 Washington.

Reconstructing Ancient Environments. (summer and
 fall 1979).

History of the Pacific Northwest Environments.
 (summer 1980).

An Archaeological Experience in Renton. (summer 1980,
 mini-field schools for the public).

INTERESTS:

Areal Interests: North America
 Arctic

Topical Interests: Human Paleoecology
 Faunal Analysis
 Theory and Method
 Early Man in the New World
 Culture Contact (archaeological
 manifestations)