CHIPPED STONE RAW MATERIALS AND
THE STUDY OF INTERACTION

by

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ABSTRACT

It is argued that chipped stone raw materials are equally, if not better, suited to the study of interaction than ceramics, which traditionally have provided the data base for such studies. Through examination of the entire range of raw materials represented in lithic assemblages, changes over time in interaction within a study area and between the study area and source locales can be documented.

A source survey identified general source locales for 95% of the Black Mesa, Arizona, chipped stone raw materials. Descriptions of the raw materials and their source formations are provided, as are maps on which specific sources have been pinpointed. This source information should apply to much of northeastern Arizona and the Four Corners region because the same formations exist throughout.

Artifacts from 97 sites located by the 1975 survey of Peabody Coal's eastern lease area were visually compared with source samples and assigned to sources. These data were used to test culture change models in which an increase in interaction over time has been proposed as one of the causes for the ultimate abandonment of northern Black Mesa.

Results of cluster and factor analyses supported each other and demonstrated a dramatic shift from the almost exclusive use, during Basketmaker times, of a single locally available material, white baked siltstone, to the use of a wider variety of materials during Pueblo

times, including a number of imported cherts, basalt, and obsidian. The abruptness of the shift lends credence to the argument that there was a gap in the occupation of northern Black Mesa sometime between A.D. 1 and A.D. 800. There also is support for seasonal occupation of the mesa during the early periods.

Development of exchange ties and/or rights of access and/or source location information for nonlocal materials progressed slowly, beginning with the individual appearance of materials from different sources at different sites. When combinations of nonlocal materials began to occur in sites, they first were of materials from distant sources located in the same direction, suggesting an orientation to ties with a specific area. Toward the end of the sequence, imports from all directions were combined with all others at sites, indicating an increased level of exchange among Black Mesa sites. At the very end of the sequence, when the system was breaking down and a reversion to hunting and gathering has been suggested, the significance of imports in the assemblages decreased and there was increased use of local materials again.

TABLE OF CONTENTS

CHAPTER Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

INTRODUCTION

Interest in the study of prehistoric interaction and in the origins of chipped stone raw materials is not new to archaeology. For example, Squier and Davis (1848) wondered about the source of Hopewellian obsidian as long ago as the mid-1800s. However, not until recent years have the two interests merged into one. There are several reasons for this long separation and recent union.

First, the primary data for studies of interaction have been ceramic artifacts (Deetz 1965; Longacre 1970; Hill 1970). However, recent research has questioned the assumptions used to describe interaction using ceramics (S. Plog 1977b; Stanislawski 1978). A number of these assumptions, which for a time were entrenched firmly in the literature, have been demonstrated to have little basis in fact. Difficulties arise in the identification of the locus of ceramic manufacture because it is a complex and additive process that leaves little in the way of manufacturing by-products.

The renewed interest in chipped stone source analyses is partly a result of the ability to fingerprint sources chemically. Once the source of the parent rock is identified, the origin of the single material component of lithic manufacture is known. Tracing its distribution across the landscape proves less complex than for ceramics because lithic manufacture is a subtractive process that does leave waste products (Johnson 1977). Recent studies have gone beyond associating artifact and source and have used the distribution of chipped stone raw materials across sites for describing prehistoric exchange. Thus, it will be argued that chipped stone raw material source analyses facilitate the study of prehistoric interaction as documented by prehistoric exchange.

Previously, such studies tended to concentrate on a single exotic raw material, often obsidian, and its distribution at a few large, and usually widely spaced, sites. This dissertation will not be a traditional exchange study. Instead, it will investigate changes in prehistoric interaction on Black Mesa, Arizona, through the study of chipped stone raw materials. The data base used in the analysis is more complete than usual owing to the 100% survey of a 130 km^2 area and the compilation of source information for almost all of the chipped stone raw materials present on Black Mesa sites.

The study begins by presenting a brief history of the evidence for interaction in Southwestern archaeology. Because ceramic artifacts have been employed almost exclusively as the data for this research domain, they serve as the focal point of the discussion. The argument is made, however, that chipped stone raw materials are equally, if not better, suited to this task. Brief summaries of previous chipped stone raw material analyses are presented and their limitations are discussed in contrast to the proposed goals of the present study.

The culture history of the Kayenta Anasazi region follows. Although the focus is on Black Mesa, this chapter places the Black Mesa cultural manifestations in context. The time frame begins with Paleo-Indian and continues beyond the end of the Black Mesa phase sequence through the abandonment of most of the rest of the region. The particular significance of the larger region for this study lies in the fact that many of the chipped stone raw materials used on Black Mesa derive from sources located in other Kayenta Anasazi study areas (and beyond). Thus, the data on source locations should obtain for other of these areas as well.

The primary goal of this research is to test the increase in interaction proposed in many of the Black Mesa culture change models. These models will be presented in detail and will be followed by a discussion in which the increased interaction hypothesis is placed in the context of the distribution of the chipped stone raw materials. Interaction will be traced over time with the expectation that the sharing of raw materials, thus interaction, increased up to the time of abandonment.

The Data Base chapter will be divided into two parts. In the first part, the physical environment will be described. Short sections on modern and prehistoric climate and vegetation that aid in our understanding of potential subsistence strategies will be followed by a detailed description of the bedrock geology of the Black Mesa region. A separate section describes the findings of the chipped stone raw material source survey. Specific source locations are provided in Appendix A. In the second part of this chapter, site recording procedures are outlined and the basis for site dates is established. The data base (97 sites) used in the final analyses is considerably smaller than that developed by the 1975 survey (765 prehistoric sites). The reasons and strategies used in the final site selection process are defined in this chapter.

Chapters I through IV, outlined above, provide the background information necessary for testing the model of increased interaction. In Chapter V the model is tested through a series of cluster and factor analyses. In the conclusions, the objectives of the study are restated and evaluated in light of the test results. Shortcomings are noted and potential future research directions are suggested.

CHAPTER I

INTERACTION AND RAW MATERIAL ANALYSES

Introduction

As has long been recognized, the inhabitants of individual prehistoric settlements did not live in isolation. Interaction among prehistoric peoples has been the focus of much archaeological research. Interaction is used here in the dictionary sense, i.e., action upon one another. Interaction and exchange will be used interchangeably in this study, as it is recognized that transfers of goods, services, and ideas often accompany one another.

> Exchange activities are deeply embedded in the cultural matrix of most societies, with effects on almost every aspect of culture. For this reason, exchange can be analyzed on every level from the psychological to the international, and in the context of any other cultural system (Luedtke 1976:2).

Some sociologists (Homans 1958) would take this statement even further and say that all social behavior is exchange in either material or nonmaterial form (Renfrew 1975).

Luedtke (1976) has outlined a number of the potential effects of exchange. It can be the source of new ideas that are adopted by or adapted to the existing culture, it can help equalize environmental inequities by reinforcing mutual-aid relationships, it can help maintain boundaries by enabling people to live in otherwise marginal environments, and it can extend social relationships beyond areas reached by kin ties. These examples should suffice to suggest the variety of ways in which the effects of exchange operate on a culture. In the following pages specific examples of exchange within the northern Southwest will be presented, as will a review of ceramic versus lithic studies of interaction (or exchange).

Interaction in the Prehistoric Southwest

In a recent article, S. Plog (1980b) pointed out the fallacies in the arguments presented for village autonomy in the prehistoric Southwest. Authors such as Dean (1970), Jennings (1966), and Gumerman and Euler (1976) have made statements concerning the seeming lack of contact among sites in the Kayenta region. Similar statements have been made for other areas of the Southwest (Leone 1968). These authors, interestingly enough, have emphasized environmental factors in their explanations of culture change (see Chapter II).

The fundamental assumption behind arguments for the lack of exchange usually is homogeneity in the environment that makes needed resources available to all (Eggan 1950). Two problems are associated with this assumption. First, although resources may seem to be distributed evenly, productivity and/or quality may be highly variable. Ford (1972a) addresses this issue on the local level and F. Plog (1978) points out critical differences in the environments of the Eastern versus the Western Pueblos. Second, exchange often takes place for reasons other than environmental inequalities (recall Luedtke's examples, this chapter). Further, recent research by Wobst (1974) has suggested that, due to the small size of most Southwestern villages, exogamy would have been necessary to maintain a suitably large marriage network for continuing the population. These ties would have been accompanied, perhaps maintained, by the exchange of information and material goods. Arguments concerning stylistic similarity in pottery designs as evidence for village autonomy also have been refuted by S. Plog (1977b, 1980b).

Finally, arguments for village autonomy have relied upon the relative absence of trade goods. However, S. Plog (1980b) points out that, because local ceramic production has been assumed, archaeologists generally have not pursued the rigorous testing necessary to prove otherwise. It might be added that a lack of interest in lithic artifacts (in the early years of excavation on Black Mesa, at least) resulted in the failure to recognize that a large proportion of these materials were imported as well.

In the following sections evidence for interaction among Southwestern sites and between the Southwest and Mesoamerica will be presented.

Southwestern Exchange

Although some researchers have argued to the contrary (Dean 1970; Gumerman and Euler 1976; Jennings 1966; Leone 1968), prehistoric Southwesterners were not isolationists. Recognition of prehistoric Southwestern trade items occurred prior to the recent popularity of chemical analyses. One unusually diverse piece of evidence for this postulated exchange is in the form of a magician burial from Ridge Ruin (McGregor 1941).

> This Ridge Ruin magician possessed or had buried with him objects traded from afar with basketry and carved wood from Hohokam centers and the Verde Valley, painted and carved sticks from Wupatki, lignite mirrors from either Betatakin and Marsh Pass or perhaps from Pueblo Bonito, pottery from many adjacent Pueblo cultures, copper from the Verde Valley, cinnabar from the Gila Basin (near Globe, Arizona), pigments from the Painted Desert, lac from the Salt River Valley, turquoise from probably Los Cerillos, New Mexico (or possibly Nevada), and shells from the Pacific (California) coast and from the Gulf of California (Sonora) coast (Tower 1945:36).

Evidence such as this burial makes the case for isolation extremely hard to argue.

Perhaps the most obvious trade item is marine shell. "All these shells were gathered from the ocean, and so they all represent commerce" (Colton 1941:313). They originated in the Gulf of Mexico, in the Gulf of California, or along the Pacific coast and have been found in varying forms at sites across the Southwest since Basketmaker times (Brand 1938; Tower 1945). Shell found at the earliest sites originated in the Gulf of California and from along the California coast. Shell that originated in the Gulf of Mexico wasn't found at Southwestern sites until Pueblo times. The Hohokam and Mimbres areas were richest in shell. Shell frequencies decreased to the north; they were extremely low in the San Juan area (including Black Mesa). Tower (1945) believed that the extraordinary amount of shell found at Pecos Ruin indicates that it was involved in shell exchange, probably between the Southwest and the Western Plains. Ninety percent of the shell artifacts recovered were worked and probably were used for ornaments.

Certain stone materials such as obsidian and basalt are known to have limited source distributions in the Southwest (Jack 1971; Schreiber and Breed 1971); however, they were traded widely. Brown (1981) recently reported results of X-ray diffraction done by Frank Findlow on obsidian from Nuvakwewtaga (Chavez Pass Ruin). Government Mountain, near Flagstaff, provided most of the obsidian found at that site, as well as most of that found in the Black Mesa area (see Lee Sappington's results for Black Mesa obsidian in Chapter IV). Other evidence of trade at Nuvakwewtaga includes,

> . . . at least 60 decorated ceramic types from nearly all parts of the Southwest except the Hohokam area (Upham, Lightfoot, and Feinman 1981), turquoise from the Cerrillos and Azure source areas in New Mexico sourced by neutron activation analysis (Upham 1980:332), . . . worked and unworked marine shell from the Pacific and Gulf of California, and a variety of other exotic raw materials and artifacts (Brown 1981:6).

Basalt, generally not considered a particularly desirable chipped stone raw material, was used to a great extent, particularly during the later time periods, in the Chevelon Drainage where it is not available locally (Green 1975, 1976; F. Plog 1977). Colton (1941) enumerated a number of instances of the use of nonlocal stone materials in areas across the Southwest, and more recently researchers such as Cameron (1981), Findlow and Bolognese (1980), Fernstrom (1980), Borger (1979), and Hudson (1978) have taken an interest in this subject. Southwestern turquoise sources also have been pinpointed, and turquoise from them has been traced well into Mesoamerica (Weigand et al. 1977).

Recent studies are beginning to demonstrate that the magnitude of prehistoric ceramic exchange in the Southwest was much greater than had been believed previously. Although Shepard's analyses of La Plata, Pueblo Bonito, and Pecos pottery indicated large-scale prehistoric trade, the magnitude of this trade across the Southwest has only begun to be appreciated (Shepard 1936, 1939; Judd 1954). In fact, Cordell and Plog (1979) have argued that the magnitude of this exchange was so great that it had to have been controlled by local and regional elites. They believe that reciprocal exchange would not suffice to explain such large-scale, long-distance exchange. This idea will be expanded in the discussion below on exchange with Mesoamerica.

Atomic absorption, X-ray fluorescence, petrographic analysis, and design element analysis have been used to demonstrate statistically significant differences between paste, temper, and designs of Little Colorado and Cibola White Wares, the two most common black-on-white ceramic classes in the Chevelon Drainage (S. Plog 1977b, 1980b; Wait n.d.; Garrett n.d.). These results suggest that thousands of Little Colorado White Ware vessels were imported into the Chevelon region, probably from the area north of the Little Colorado River.

Black Mesa ceramic analyses have provided similar results. Petrographic analysis of black-on-red vessels demonstrated that a nonlocal mineral, andesite, was the temper used in San Juan Red Ware vessels (Garrett 1979). This material is available in southeastern Utah and southwestern Colorado, where San Juan Red Wares also are abundant. These imported ceramics were the major red wares on Black Mesa sites from A.D. 775 to A.D. 975 (S. Plog 1980b), and the exchange apparently involved sites of all sizes (Hardy et al. 1980).

Neutron activation analysis of black-on-white ceramics also from Black Mesa has indicated paste compositional differences between Sosi Black-on-white bowls and jars and between Sosi and Dogoszhi Black-on-white. Some sites have homogeneous ceramic pastes regardless of type, which has been interpreted as indicating local production. Others show strong differences not only between types, but, within the Sosi type, between bowls and jars. This tentatively has been inferred as evidence of at least partial importation (Deutchman 1980).

Whittlesey's study (1974) of Grasshopper ceramics suggested that vessels intended for export were built to be nested to facilitate transportation.

Ceramics apparently also were imported to Chaco Canyon on a large scale (Toll et al. 1980). Analysis of temper, which often was nonlocal and has never been found in raw form at sites, and analysis of iron content of clay through refiring, support this contention. Primary supply areas seem to have shifted over time from the Chuska Valley to the west during the early periods, to the San Juan area during later time periods. Reasons for the importation of ceramics there include the scarcity of fuel necessary for production.

These examples are not intended to provide an exhaustive list of trade contacts within the Southwest, but rather to give an indication of the magnitude and diversity of these contacts where they have been studied. Other authors have focused on interaction between the Southwest and surrounding regions (Ford 1972b; Kelley and Kelley 1975; DiPeso 1968). The following section will concentrate on the nature of Southwestern-Mesoamerican contacts.

Southwestern-Mesoamerican Exchange and Interaction

Kelley and Kelley (1975) pointed out that the earliest Southwestern researchers believed that Anasazi culture was derived from Mesoamerica, but that later "new archaeologists" discounted that view in favor of internal evolution. A return to the earlier position has been favored by a number of archaeologists (Kelley and Kelley 1975; DiPeso 1968; Schroeder 1965; Ferdon 1955).

> We believe that pre-Hispanic Anasazi development throughout represents not evolution within an isolated cultural universe, but rather a series of evolutionary steps which were, in themselves, directly inspired and shaped by cultural emanations from the mesoamerican [sic] cultural hearth, albeit conditioned by local geographic influences, influences from other adjacent non-southwestern cultures, and by the phenomenon of cultural "drift." We refer not only to somewhat vaguely conceptualized "influences" from Mesoamerica, but to identifiable southwestern responses to specific historic events and cultural changes in hearthland Mesoamerica (Kelley and Kelley 1975: 179).

The Kelleys followed Schroeder's (1965) use of "soft-diffusion" as group-to-group contact and "hard diffusion" as organized commerce with the actual presence of donor culture members. They believed there was constant soft diffusion from Mesoamerica to the Southwest and some hard diffusion. The introduction of domesticated crops and their associated technologies are examples of the former, whereas pochteca (merchant) trading centers represent the latter. The Kelleys argued that the Great Kivas at Chaco Canyon were pochteca trading centers and that the Mesoamericans had sufficient control over the inhabitants to induce them to mine turquoise for export to Mesoamerica. Their reconstruction of Anasazi prehistory parallels Mesoamerican prehistory with variations in the amount of influence strongly affecting the evolution of Anasazi culture.

DiPeso (1968) also subscribed to this view in his interpretations of Casas Grandes. He saw this very large site beginning about A.D. 950 as a base of operations for the Toltec pochteca. Evidence has been found there for the manufacture, storage, and distribution of many specialty items such as copper bells, shell jewelry, and macaw and turkey feathers. The halting of construction there in the mid-thirteenth century was tentatively attributed by DiPeso to the shift to Aztec control in the south.

McGuire's recent article provides a comprehensive review of the material evidence that has been presented in support of the pochteca theory.

> Support of this theory is based on four lines of argument: (1) the presence of Mesoamerican-derived traits in the Southwest, (2) the identification of presumed pochteca burials in the Southwest, (3) the identification of presumed pochteca outposts in the Southwest, and (4) the presumed missionization of the Southwest by Mesoamerican cults (McGuire 1980:4).

He tackles each of these areas separately and determines that (1) although exchange has been demonstrated, cultural intervention has not; no single place in Mesoamerica has been identified from which the traits held in common could have emanated; (2) so-called "pochteca burials" are unique only in the quantity of grave goods and may be from local high-status individuals; (3) evidence for the introduction of Great Kivas as pochteca outposts is not as good as evidence for their local development; and (4) the Mesoamerican symbols that are used as evidence of missionization by particular cults were shared widely across Mesoamerica and fit better with a general model of interaction rather than one of missionization. In sum, he found little evidence for direct trade with central Mexico in contrast with that found for northwest Mexican-Southwestern trade and that "this interaction both influenced and changed due to changes in social complexity, markets, and access to natural corridors of communication in both regions" (McGuire 1980:33).

F. Plog et al. (1980) also recently criticized the pochteca theory because of reliance on diffusion as an explanation and because the evidence allows for a number of interpretations, not only the ones the "imperialist position" chooses to present. However, these same authors also have criticized those who hold the "isolationist position" that believes Anasazi culture was the product of purely local development. The latter position, according to Plog et al. (1980), ignores the amount of Southwestern turquoise that reached Mesoamerica and shows too much concern for purely material goods and not enough interest in information exchange.

These authors have developed a model that avoids the extremes of total isolation and heavy-handed Mesoamerican control. Both Mesoamerica and the Southwest participated in a "world system" in which craft specialization occurred at a number of population centers. The economic and political relationships between these centers and their hinterlands probably changed over time as did the relative power structure between centers. Although the majority of exchange took place locally, there was exchange of luxury items among the elites of the various centers.

This model appears to offer a good compromise because, as pointed out, the isolationist model ignores evidence for interaction and the imperialist model draws many possibly unwarranted conclusions from the data. More emphasis will be placed through the use of this model, on issues such as directionality of the exchange, relationships between centers and their hinterlands, interaction within regions that had no apparent centers, and the way in which prestige items became valuable.

None of the relevant prestige goods have been found as yet on Black Mesa, nor, possibly due to the absence of population centers there, are they likely to be found. The centers of population agglomeration in the Kayenta Anasazi area, such as Betatakin and Long House Ruin, were occupied after the abandonment of Black Mesa. Black Mesa, then, should fall into the category of regions with no center. Research on lithics (Green, in press) and ceramics (S. Plog 1978a) has already discerned ties with other regions, such as Mesa Verde, that have population centers. Further research might focus on the nature of these ties by studying sites on Black Mesa that have the trade items and similarly examining the Mesa Verde (or other) collections for artifacts of Black Mesa origin.

Ceramics as Evidence of Interaction

Ceramics as Cultural Markers

Because ceramic artifacts have received the bulk of attention in the literature on interaction, they will provide the focus for this discussion of previous interaction analyses. It will be argued later that this emphasis is not wholly deserved and that certain properties of lithic artifacts and their manufacture (unrelated to style) render chipped stone a suitable, perhaps superior, referent for interaction analyses. The original reason for the focus on ceramics, as opposed to other artifact classes, was their attractive appearance which stimulated the acquisitive interest of museums. Detailed study of ceramics was aided by their indestructibility, abundance, wide distribution, plasticity, and ease of collection. Such studies produced increased knowledge of the spatial and temporal variability in ceramics and they came to be used to define cultural units (Kidder 1924; Colton and Hargrave 1937; Colton 1939, 1955).

Early researchers--e.g., Kidder (1924)--used ceramic artifacts to differentiate cultures. The scheme by which most ceramic variability in the Southwest has been ordered was first presented by Colton and Hargrave (1937) and supplemented by Colton (1955, 1956). Variability across space and time in morphological attributes was recognized. However, after a time, some ceramics became so strongly associated with certain periods in certain areas that mere location sometimes was used to type them. An example from Black Mesa involves the classification of all white ware as Tusayan White Ware because of the assumption that all white ware on Black Mesa was sand tempered. Closer examination revealed a number of sherds with sherd temper, which more properly should have been classified either as Mesa Verde or Little Colorado White Ware (Shirley Powell, personal communication). On a more general level, Fish (1978) cautions against assuming that there will be consistency between artifact analyses done by different individuals. In an experiment comparing individual ceramic analyses of the same Tusayan gray and white wares, observers were found to disagree 22% to 30% of the time.

The earliest interaction studies in archaeology were concerned with construction of time-space frameworks and, indirectly, with recognizing that contact between cultures had occurred; the nature of the contact was not of principal importance (Renfrew 1975). Instead, evidence of contact, usually in the form of intrusive ceramics, was used to obtain chronological control in areas where previously it had been lacking and/or to correlate regional sequences (Colton and Hargrave 1937; Flannery 1976). As Martin and Plog (1973:240) noted, "Spatial and temporal variability in ceramic artifacts has been the most important single datum used by archaeologists in building chronologies and defining culture areas."

Ceramic artifacts have, on the whole, proven extremely useful in time-space analyses. This type of analysis, however, treats them as representative of, but not an integral part of, cultural systems. Thus, a wide variety of problems involving ceramics, as they moved through the cultural system, were not investigated. As independent dating methods improved (e.g., dendrochronology and radiocarbon), the focus of ceramic analysis turned more toward spatial rather than temporal problems. It wasn't until the 1960s that ceramic analyses began to be used to investigate aspects of the social organization of groups that used them.

Ceramics and Social Organization

Beginning in the 1960s and extending into the 1970s a number of researchers (Cronin 1962; Longacre 1964, 1970; Deetz 1965; Whallon 1968; Hill 1970; Tuggle 1970; Clemen 1976; and others) became interested in studying the distribution of ceramics as an indication of social groupings at various levels of organization. Deetz (1965:2) provided a clear statement of the general model employed in these analyses:

> The stylistic attributes of ceramics produced by a society characterized by matrilineal descent, matrilocal residence, and households composed of social units of greater complexity than the nuclear family will exhibit a high degree of association, forming a series of clusters, each of which is the result of having been passed, relatively intact, from mother to daughter . . . with the residence and/or descent pattern forming the channeling device. If these channeling devices are removed, through a change in descent and/or

> residence, clusters which were formerly possessed of a relatively low internal variation, and high intergroup variation, will exhibit an increase in internal variation with a corresponding decrease in intercluster variation.

Although Deetz actually studied the ceramics from a Plains Arikara village, the majority of the applications of this model have focused on prehistoric populations from the northern Southwest. The Pueblo Indians provided the Southwestern ethnographic analogy upon which the model is based.

In 1968, Stanislawski began field work among the Hopi-Tewa to achieve a better understanding of relationships between pottery styles and social organizational units such as clans. He studied the networks of ceramic instruction and how artifacts became part of developing sites. His conclusions, basically, were that the ethnographic analogy rested on many unfounded assumptions; in some areas it was too simplistic, and in others it simply was wrong. For instance, the assumption that mothers teach daughters the art of ceramic manufacture isn't wrong; it is only a part of the picture. Women also learn from aunts (of different clans), neighbors, mothers-in-law, and other females with whom they are close. Often pots are made by ad hoc work groups, so a single pot may be the product of the work of a number of women. Stanislawski (1978) believed that the localized ceramic design distribution is probably the result of the ad hoc work groups rather than clans, which haven't been localized since at least the 1880s. If clans were localized prior to the 1880s, then the situation that Stanislawski studied may not be analogous to the prehistoric situation. However, there still are valuable insights to be gained from his studies.

Stanislawski related the difficulties of defining a "culture" on the basis of archaeological materials to the corresponding materials in the ethnographic situation. He found that factors such as manufacturing techniques, temper, and clay, which usually are assumed to remain constant within a culture, sometimes vary. For example, although clay usually is mined near the villages, there are instances where raw clay is transported. "These cases cause confusion for the archaeologist, for we have always assumed that such divergent production methods were cultural markers" (Stanislawski 1978:214).

Ceramic exchange among villages also introduces confusion. "For example, Hopi-Tewa women trade with particular potters in Acoma or Zuni. These long-lasting individual ceremonial trade partnerships are similar to those of the Yir Yiront or the Kula relationships of the Trobrianders" (Stanislawski 1978:222, references omitted). This type of trade would increase heterogeneity within the village but would decrease it within the region. Homogeneity within the region can be produced by other factors also.

> No less pertinent to the subject of the economics of the potter's craft is the question of specialization and exchange within a region where pottery appears to be stylistically uniform. Such uniformity is generally considered indicative of the sharing of technical and stylistic standards by a group of pottery-making communities. But ethnographic records remind us that a comparable distribution of pottery types may be brought about by various trade relations: one village may supply all the pottery for the settlements of a region; a number of villages may produce distinctive pottery in consequence of special resources and unique local tradition and general distribution and intermingling may be brought about by exchange; the production of certain essential forms may be general and a few villages may specialize in more elaborate types made for trade (Shepard 1954:357).

Results from Whittlesey's (1974) analysis of Grasshopper ceramics and Deutchman's (1980) analysis of Black Mesa ceramics suggest that, even within a single type, certain design configurations may have been produced locally while others may have been imported.

S. Plog instituted a reanalysis of the 20 sherds that Longacre (1964) used to demonstrate that all pottery from Carter Ranch had been made locally because he believed some of it may have been imported. He found that ". . . neither the original analysis (Porter 1976, personal communication to S. Plog) nor a reanalysis of the same thin sections (Garrett n.d., personal communication to S. Plog) support the conclusion that the paste of all the sherds was the same" (S. Plog 1977b:65). The fact that some of the pots that Longacre used in his analysis were not manufactured locally certainly casts some doubt on the meaning attributed to the ceramic clusters he identified. (Most of the researchers working during the 1960s and 1970s didn't bother with petrographic analysis; with the exception of Tuggle (1970) they assumed that the pottery was made locally.) Even Stanislawski's (1978) conclusion that the clusters derived from ad hoc work groups is thrown into doubt by the presence of nonlocal ceramics.

S. Plog's (1977b) approach went beyond criticism of previous research to explore which variables might have had an effect on design variability. He found that at least some of the design variability used in the earlier studies to indicate intensity of interaction actually was related (in order of importance) to exchange, temporal variability, and design differences between different vessel forms. Thus, although the earlier researchers were moving in a productive direction by studying ceramic design variability in relation to social organization, their model was not tested adequately and they ignored the effects of the rest of the cultural system.

An alternative model proposes that stylistic variation is a means of information communication (Wobst 1977; Gorman 1972; Braun and Plog 1980) rather than a result of interaction intensity. The function of communicating messages such as social group affiliation and/or ownership is to make interaction between socially distant individuals more predictable. The social distance between the sender and receiver would have to be far enough to ensure that simple verbal communication wouldn't be more expedient and close enough for the message to be understood (Wobst 1977; Renfrew 1975).

Braun and Plog (1980) have developed this concept still further. They suggest that there are at least two classes of material evidence for interaction among small-scale societies--(1) stylistic and (2) exchange of goods--which provide complementary, not equivalent, information. Stylistic messages would communicate and maintain social distances on a large scale, as mentioned above, and thus would change gradually. Evidence of exchange, however, is expected to parallel more accurately short-term fluctuations in the social environment because it is a negotiated act presumably between individuals each with his own economic interests. So, although the potential exchange channels are defined by the more stable criterion of social differentiation (Firth's 1964 use of social structure), short-term needs may be served either within these potential channels or outside them (Firth's 1964 use of social organization). If these needs more often are served outside the traditional channels, new ones should become more stable and social change will have occurred (see Chapter III).

Both types of studies, stylistic and material exchange, can provide useful information; but, as will be argued, lithic raw material studies are less complex to perform than ceramic exchange studies. This is not to say that studies of ceramic exchange are of little utility; it is to say, however, that another very useful class of data has been ignored for too long.

The above discussion portrays the complexity of ceramic manufacture in relation to its final distribution in the cultural system. The most critical points are that there are a number of elements that contribute to the ceramic end-product, including manufacturing technique, clay, temper, design, paint type, and vessel form. Although generally it is assumed that all of the elements are indigenous to the group under consideration, the arguments presented earlier demonstrate that the opposite often is the case. The clay, temper, paint, or even the finished vessel may have been imported, and the method of manufacture, design style, and/or vessel form may have been copied or might have been an innovation. The possible combinations of these alternatives have the potential to become quite complex. Because ceramic manufacture is an additive process, and mistakes often can be reworked before firing, little, if any, evidence of manufacture remains for the archaeologist. Some type of chemical or physical analysis should be done in addition to the typical ceramic analysis to determine the origins of the various components of the vessels.

Chipped Stone Raw Materials as Evidence of Interaction

The Utility of Lithics in the Study of Exchange

One can argue that the qualities, such as abundance and durability, attributed to ceramics are equally applicable to other artifact classes.

> By focusing on designs, and studying spatial and temporal variability in great detail, archaeologists have created plasticity. It remains to be shown that chipped or ground stone tools would not appear equally plastic if subjected to the same minute attribute analyses that have been made on pottery (Martin and Plog 1973:241).

This statement should be tempered as a result of more recent lithic analyses. Although successful attempts have been made to stylistically categorize lithics made by an individual flintknapper (Gunn 1975, 1977; Johnson 1977), projectile points are still the only commonly used chipped stone cultural marker in the New World. This circumstance probably can be attributed to properties of the material and the limited number of functionally useful forms of chipped stone.

The most distinctive feature that characterizes most Southwestern lithic assemblages is the raw material from which it is manufactured. Study of interaction based on the distribution of chipped stone raw materials is facilitated by the following factors.

Lithic manufacture, as opposed to ceramic manufacture, is a subtractive process. Waste products are being produced continually during manufacture and generally are left near the locus where manufacture took place (Collins 1975; Johnson 1977). Even if an effort is made to retrieve the waste material, it is unlikely that all of the small bits of shatter could be collected.

The vast majority of lithics found by archaeologists were manufactured from a single element: stone raw material. (It is only in extremely rare cases that a wooden handle or arrow shaft is preserved.) If an area is geologically distinct from surrounding areas, as Black Mesa is, it should be a relatively simple matter to determine whether a material is available locally. A very simple example is the absence of igneous rock on Black Mesa. Any obsidian or basalt found there was imported. Even if chemical or physical tests are deemed necessary, the test need only be conducted on the single material type, not on several materials as with ceramic clay, temper, and paint.

Exchange of materials occurred in the lithic subsystem, but it can be argued that this exchange is simpler to document because fewer elements were involved. Although there is a continuum of forms in which lithic materials could have been exchanged--i.e., raw materials, cores, usable flakes, blanks, and finished tools--the information necessary to trace this exchange is left on the ground (or is conspicuously absent).

Since fewer assumptions concerning origin(s) of material(s) are necessary for analysis of chipped stone procurement, the study of this subsystem should facilitate the study of interaction. This particular analysis will deal with the lithic subsystem and interaction on the intersite level, but there is potential for this type of study on the intrasite and regional levels as well.

Chipped Stone Raw Material Source Analyses

Source identification. Establishing points of origin for raw materials used in chipped stone tool manufacture has been an archaeological concern since at least the mid-1800s when Squier and Davis (1848) speculated on the source of Hopewellian obsidian. Determination of obsidian source locales remained in the realm of conjecture until techniques that could match artifact and source on the basis of shared unique chemical composition were developed. These techniques include optical spectroscopy, X-ray fluorescence, and neutron activation analysis.

Briefly, in spectrographic analysis, a sample of some raw material is heated and measurements of the spectral lines created are taken for an array of elements ranging from one part per million to 1%. In X-ray fluorescence, "the test specimen is bombarded with X-rays and the characteristic fluorescence that is then emitted by chemical elements receiving this induced activation can be measured spectrometrically and the elements can be identified" (Matson 1970:599). In neutron activation analysis, samples from sources, artifacts, and standards of known elemental composition are irradiated with thermal neutrons. The resultant activities of radioactive isotopes of various elements are monitored. As the isotopes decay, gamma-ray pulse heights are recorded for each element present, reflecting relative abundance of elements.

The chipped stone raw material type that most commonly has been the subject of these tests is obsidian. This interest in obsidian stems from the fact that prehistorically it was traded widely. There is much variation in appearance within a single source; thus chemical identification is necessary to determine the specific obsidian flow of origin (Cann and Renfrew 1964). Some of the earliest raw material source studies focused exclusively on the use of these newly developed means of chemical characterization (Frison et al. 1968; Griffin et al. 1969).

Frison et al. (1968) identified obsidian sources for six sites in north-central Wyoming through neutron activation analysis. The Wyoming data indicated that material from the Yellowstone National Park area had been in use at these sites since at least 8000 B.C. One material, with slag particles, was found to be from the Powder River in Montana and was used only in late prehistoric times. The findings of Frison et al. caused some concern when they realized that material from a good source of obsidian in the Grand Tetons did not appear in their artifact assemblages. These researchers were able to correctly visually isolate material from one source on the basis of the included slag particles. However, differences in the amount of light transmitted through the materials, i.e., opaque versus translucent, were not related to different sources and so could not be used as a distinguishing criterion. Cann and Renfrew (1964) had similar difficulties with visual sorting of Mediterranean obsidians.

It should be realized that geologic source characterization (not bedrock outcrop, however) can be accomplished fairly accurately through visual means for many materials other than obsidian. In Luedtke's (1976) analysis of Michigan cherts, she found only an 8.7% discrepancy between the source assignments made visually and those made by neutron activation analysis. This error rate is not a constant, but it does indicate that visual sorting of cherts is reliable within an acceptable error range. In assemblages with a wide variety of different raw material classes (e.g., petrified wood, sandstone, chert), this error rate should be reduced. Although the ideal course would be to chemically characterize all of the materials to be sure of correct source identification, this approach is financially infeasible in most cases, and this study is no exception. Thus, the source identifications for this analysis, with one exception, will rely upon the results of the visual identifications. Lee Sappington of the University of Idaho at Moscow performed X-ray fluorescence on obsidian artifacts from Black Mesa sites (See Chapter IV).

Distance decay models. Some of the earliest chipped stone raw material studies for which models of exchange systems were developed were done by Renfrew, Cann, and Dixon for obsidian in the Mediterranean area and the Near East (Cann and Renfrew 1964; Renfrew et al. 1968; Cann et al. 1970). Trace elements of various obsidians were measured through optical spectrography in order to associate artifacts with their source areas.

The Near Eastern analysis facilitated documentation of the distribution for percent of obsidian in the total chipped stone industry for sites spread over an area close to 1,000 km in diameter. Obsidian comprised greater than 80% of the total raw material assemblage within a 300 km radius of the source (the "plateau effect"). This area was termed the supply zone. Beyond this area, in the contact zone, the percent of obsidian in the assemblages dropped at an exponential rate to less than 10%.

Several models were advanced to account for the supply versus contact zone phenomenon including differential ease of direct access and differential trading opportunities. A down-the-line type of overland trade was postulated for the contact zone in which each village retained a portion of the material and passed on the remainder.

> Since, however, this "plateau effect" near the origin is characteristic of regression relationships resulting from a random walk process, and has been discussed as a normal characteristic of interaction behaviour, the obsidian curve need not be divided in two. The whole pattern of contact may be seen as "down-the-line" random walk movement (Hodder and Orton 1976:114).

Regardless of the particulars of the interaction network, the authors were impressed by the wide area over which obsidian was circulated and the apparent duration of the contacts, suggested by the regularity of patterning.

Ericson (1977) used SYMAP, a computer cartographic technique, to depict the distribution of obsidian at 52 sites in California. He found high data values clustered around sources, with predictable falloff in accord with the Law of Monotonic Decrement. However, the falloff patterns were not symmetrical. Anomalies became apparent and were explained, at least tentatively, by invoking the existence of trails and/or intervening sources. Redistributive centers were not identified in this egalitarian system but also may have caused anomalies in the distribution.

<u>Chipped stone exchange in cultural context</u>. Wright (1969) followed the lead of Renfrew, Cann, and Dixon in obsidian analysis for

the Near East, but focused more on the economic and social contexts of use for this import. He argued that the role played by the imported item should have structured the exchange, thus functionally different sites should be examined separately at some point in the analysis. (This suggestion was followed for the Black Mesa materials, and the results are described in Chapter IV.) Wright traced the various uses of obsidian over time because, for example, if larger artifacts began to be made, larger pieces of the material would have had to be imported. He chose weight as the most appropriate measure of quantity because prehistoric transport was accomplished through human energy. The information resulting from his analysis was used to develop three alternate models of trade for the Near East: (1) sedentarization of hunting bands still utilizing distant resources; (2) seasonal movement of herds to mountain pastures as a vehicle for trade; and (3) mobile hunting bands trading with sedentary villagers.

Griffin et al. (1969) used neutron activation analysis to determine the source of obsidian found at Hopewell sites in Ohio and Illinois. Obsidian flows in Yellowstone Park were identified as the source of this material, and the same general area probably was the source of bear canines also found at Hopewell sites.

Sources of the materials and the distribution of raw material, preforms, and finished artifacts were used to trace the movement of goods through several local and regional interaction spheres. For example, the Golden Eagle site, located at the confluence of the Illinois and Mississippi rivers, and the only Middle Woodland geometric earthwork site in the lower Illinois Valley, is considered a regional transaction center. As such it would have helped relate Middle Woodland sites with each other and with groups outside the region. Six local transaction centers that are structurally similar to each other, but different from Golden Eagle, were located along the Illinois Valley floodplain, at almost equivalent distances from each other. Thus, a hierarchy of centers is envisioned within an interaction sphere.

Differences were found in the abundance and form of material items in different areas. For example, it appears that the Hopewell Site in Ohio had either special or exclusive access to obsidian due to the extremely high frequencies of it there compared with other centers (10,000 to 50 or less). This provides an example of an anomaly in the distance-decay model because the obsidian in Illinois apparently moved first through the Ohio center, even though its source was farther to the west.

<u>Studies of varied raw materials that included chipped stone.</u> Pires-Ferreira (1973) investigated the social implications not only for obsidian exchange at sites in Mesoamerica, but also for shell and magnetite mirrors. She found differences in the exchange spheres for the three as a result of ease of access, specialization, and use as status markers. Ethnographically derived models of societies with hereditary ranking were used in place of the usual Western industrial economic models. A gravity model in which both mass (in this case, population density and distribution) and distance are critical factors in the exchange of materials was employed rather than the simple distance-decay model. The data supported different trading contacts for separate

households based upon wide variation in the abundance of obsidian among houses.

Struever and Houart (1972) also used the results of various source analyses, including obsidian (Griffin et al. 1969) to construct a model for Hopewellian interaction. However, they were dealing mainly with status items and not the entire range of chipped stone materials. According to Struever and Houart, the original belief that Hopewell was a single culture resulted in part from sampling errors and in part from a "normative" definition of culture. More recently it was realized that a number of Middle Woodland complexes were involved in what came to be called the Hopewell Interaction Sphere. Interaction is evidenced by status-related items including copper earspools, chipped obsidian spears, marine-shell containers, worked bear teeth, effigy platform pipes often made from exotic raw materials, and similar burial practices. This interpretation provides an interesting comparison for the ideas of Plog et al. (1980) concerning exchange among elites in the Southwest and Mesoamerica.

Limitations of previous analyses in the study of interaction. It should be apparent from this brief history that most raw material source analyses have dealt with the movement of only a single chipped stone raw material type across the landscape. This focus necessarily limits the evidence for interaction among sites to a comparison of the abundance of that single raw material on different sites with regard to their varying distances from its source (Renfrew et al. 1968; Wright 1969). If the system under scrutiny is symmetric, that is, there is a regular decrease with distance regardless of direction from source, then the two-dimensional analyses listed above are adequate. Ericson (1977) has suggested, however, that variables other than distance, such as population and intervening sources often may override the effects of distance. He used the three-dimensional (SYMAP) approach mentioned earlier that considers the spatial patterning of the system in terms of symmetry, local and regional trends, and anomalies.

However, neither he nor others have made an effort to quantify the occurrence of material from other sources and so the varying significance of different sources remains unknown. Although the sizes of the exchange networks for these other materials probably did not equal those for obsidian, it should not be assumed that trade in them was unimportant. This more localized exchange may have been more critical to the economic system on a day-to-day basis than was the long-distance trade in obsidian.

The level of interaction studied by these earlier researchers also differs from that in this analysis. The other analyses studied distributions across areas several hundred kilometers in diameter or, for example, the state of California (Cann and Renfrew 1964; Renfrew et al. 1968; Wright 1969; Hammond 1972; Pires-Ferreira 1973; Ericson 1977). The present study is concerned with interaction among sites within a 130 km^2 area. The portion of the assemblages procured from distances exceeding 50 km is minute in comparison with that available within that radius. Whether or not this also is the case in the other study areas generally is not made clear. The focus here is on the entire chipped stone raw material procurement system, from the poorest quality local material to the finest quality materials obtained from relatively great distances, such as obsidian.

It is because of these differences in scale and orientation that the descriptions of the previous studies, including the techniques used for sourcing materials and the models through which the systems were examined, were not presented in great detail. The data for this study will be used to test the culture change models that have been developed for Black Mesa and will be presented in the section of that name.

Shared patterns of resource procurement will serve to demonstrate changing patterns of interaction among the former inhabitants of the Black Mesa sites. Bradley (1971) and others have cautioned against the use of any single artifact type to draw political or social boundaries. Demonstrating the existence of discrete areas of use of a single artifact or material type may provide tempting, but erroneous, conclusions as to the positioning of social boundaries. It is rarely the case that there is a one-to-one correspondence between a single material type and a meaningful social unit. Many other explanations could apply equally well to the same pattern. However, the demonstration of similar patterns of procurement of consistent combinations of several raw material types should lend credence to the same argument.

Detailed discussions of the culture history and culture change models for Black Mesa will be presented in the following two chapters. This background information is necessary because it, rather than the interaction studies described in this chapter, will provide the models that are tested in this study.

CHAPTER II

CULTURE HISTORY

Introduction

The focus of this chapter is the culture history of the Black Mesa study area and, for comparative purposes, other parts of the Kayenta Anasazi region. Lindsay and Ambler (1963:86) have defined the Kayenta Anasazi area as "that part of southern Utah and northern Arizona which extends from the Grand Canyon on the west to the Chinle Wash and Monument Valley on the east, and lying between the Henry Mountains on the north and the southern flank of Black Mesa on the south." The references in Table 1 are the major sources of information summarized in the chapter. Project area locations can be seen in Figure 1.

The interested reader should consult Beals et al. (1945), Lindsay and Ambler (1963), Dean (1969), Martin and Plog (1973), and/or Schroeder (1979) for more complete summaries of previous research in the Kayenta Anasazi area.

Prior to the recent investigations of the Black Mesa Archaeological Project (BMAP), the only excavation conducted on Black Mesa was that of site RB 551 by the Rainbow Bridge-Monument Valley Expedition (Beals et al. 1945). Watson Smith directed the excavation of this PI-PII site, which has several masonry rooms, a kiva, and a midden. The major archaeological goal of the larger expedition, which

Table 1. Major References on the Kayenta Anasazi Region

Area	Date	Author
Black Mesa	1945	Beals, Ralph L., George W. Brainerd, and Watson Smith
	1970	Gumerman, George J.
	1972	Gumerman, George J., Deborah Westfall, and Carol Weed
	1976	Gumerman, George J., and Robert C. Euler
	1976	Layhe, Robert, Steven Sessions, Charles Miksicek, and Stephen Plog
	1977a	Plog, Stephen
	1978	Klesert, Anthony L.
	1979	Klesert, Anthony L., and Shirley Powell
	1980	Powell, Shirley, Robert Layhe, and Anthony L. Klesert
Chinle Valley	1927	Morss, Noel
	1974	Lofton, Delsie
Glen Canyon	1966	Jennings, Jesse D.
Hopi Area	1942, 1945	Hack, John T.
	1954	Woodbury, Richard B.
	1961	Daifuku, Hiroshi
Klethla Valley (to Kaibito)	1977	Ambler, Richard, and Alan P. Olson
	1980	Anderson, Keith
Long House Valley	1971	Lindsay, Alexander J., Jr., and Jeffrey S. Dean
	1978	Dean, Jeffrey S., Alexander J. Lindsay, Jr., and William J. Robinson
	1979	Effland, Richard W., Jr.
Monument Valley	1977	Neely, James A., and Alan P. Olson
Navajo Mountain	1968	Lindsay, Alexander J., Jr., J. Richard Ambler, Mary Anne Stein, and Phillip M. Hobler
Shonto Plateau	1969	Anderson, Keith
Tsegi Canyon	1911	Fewkes, Jesse W.
	1969	Breternitz, David
	1969, 1970	Dean, Jeffrey S.
General	1919	Kidder, Alfred V., and Samuel J. Guernsey
	1921	Guernsey, Samuel J., and Alfred V. Kidder
	1939	Colton, Harold
	1973	Martin, Paul S., and Fred Plog
	1979	Plog, Fred
	1979	Schroeder, Albert H.

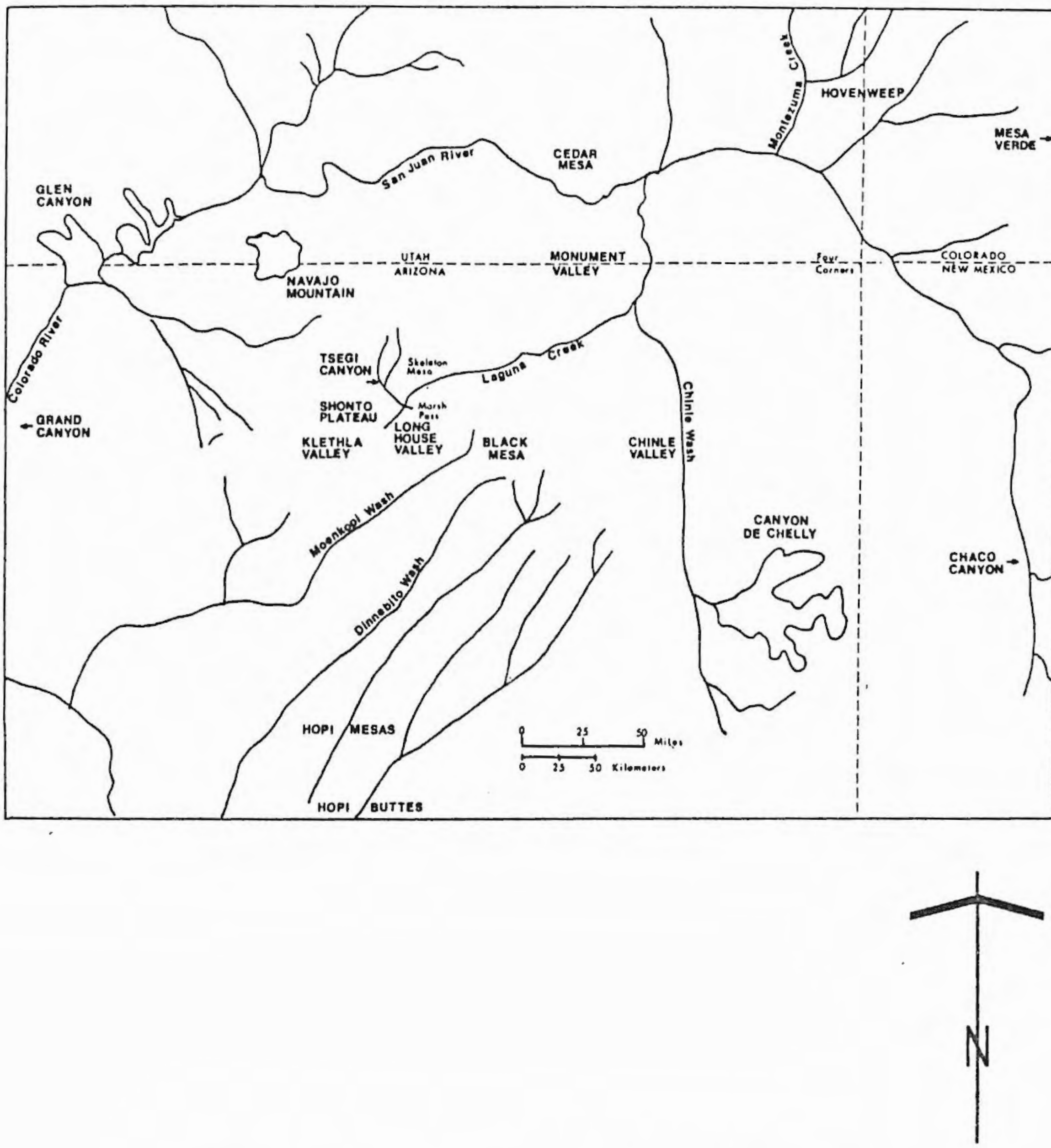


Figure 1. Locations of Anasazi project areas.

centered on an area farther north, was to refine the existing ceramic chronology.

Two other archaeological visits were made to Black Mesa prior to BMAP investigations. Milton Wetherill visited Standing Fall House, a 55 room cliff dwelling, where he wrote his name along the cliff face and the date, 1932. In 1968, Jeffrey S. Dean of the Tree-Ring Laboratory, University of Arizona, collected tree-ring core samples and assigned Museum of Northern Arizona number NA 10,105 to this same ruin (Klesert and Cowan 1978:74).

In 1967, Peabody Coal Company, which has extensive coal leases on northern Black Mesa, requested that Prescott College initiate archaeological survey and excavation so that this company could obtain clearance for future mining activities. Drs. Robert Euler and George Gumerman were principal investigators for the project until Prescott College closed and Dr. Gumerman moved to Southern Illinois University at Carbondale, where the project now is based. Dr. Stephen Plog was director of the project at the time the data for this research were collected.

Almost 160 km^2 have been surveyed, 2,500 sites recorded, and 120 excavated by the Black Mesa Archaeological Project (Klesert and Layhe 1980). Although the areas chosen for archaeological investigation on Black Mesa are a direct result of mining activity locations, they cover substantial portions of the northern part of the mesa and cross-cut the major environmental zones, from the floodplains of major washes to upland areas. The lead time and funding provided by Peabody

Coal Company have been more than adequate to support high-quality archaeological research.

The major focus of the Black Mesa Archaeological Project has been and probably will continue to be on culture change. Three aspects of culture change that have received the greatest attention thus far are: "(1) the large population increase which occurred between approximately A.D. 1000 and 1100, (2) the abandonment of the northern part of Black Mesa between A.D. 1100 and 1150, and (3) the changes in settlement patterns which occurred throughout the occupation of Black Mesa" (S. Plog 1978a:22). Because of this focus on culture change, an accurate chronological framework is critical. A chronological framework that includes changes in subsistence, site location, organization, and artifact types was developed through seven years of survey and excavation in the area. This framework essentially is based upon traditional pottery types (Colton 1955, 1956) that are used to establish approximate contemporaneity of sites. However, other variables have been introduced to ensure that distinctions between phases are meaningful in ways other than ceramic designs.

Refinements in the chronological sequence are being made continually (Layhe 1977a; Hantman and Plog 1978; Klesert 1979a) as problems with the original sequence become apparent. Independent dating methods, refined site survey and excavation techniques, broader criteria for selecting sites for excavation, and paleoethnobotanical techniques all have contributed to the revisions.

For example, once it was recognized that sites with surface masonry rubble often also have the full complement of structural types (particularly kivas and jacals), the presence of masonry rubble ceased to be a major factor in selecting sites for excavation (S. Plog 1977a). Once this change was instituted, the wide variety of site configurations recognized today became apparent. In addition, a larger number of sites that had been occupied early in the sequence are purposefully being chosen for excavation. Little was known about early adaptations on the mesa because few of these sites had been investigated. This added information from early sites has altered conceptions of subsistence strategies and site location patterns.

The original phase sequence as developed by Gumerman and Euler (1976) is illustrated in Table 2 and will be outlined in detail after a brief discussion of Paleo-Indian and Archaic periods in the Kayenta area.

Paleo-Indian

Although no Paleo-Indian materials have been recovered by the Black Mesa Project, there is evidence of these early populations from surrounding areas (Agenbroad 1967). A Clovis point was discovered in a wash east of Kayenta. It was below an outcrop of Navajo chert, the material from which it was made (Ayres 1966). In addition, a Folsom point was recovered near Mishongovi, Second Mesa (Gumerman 1966). Thus, it is possible that materials of this age may one day be found on Black Mesa.

Archaic

Little or no information on Archaic sites, or the potential for them, is presented in the reports listed earlier. This is not

Table 2. Black Mesa Phase Sequence and Pecos Classification Equivalents

Date	Black Mesa phase	Pecos classification
200 B.C.-A.D. 600	Lolomai	Basketmaker II
A.D. 600-A.D. 750	Dot Klish	Basketmaker III
A.D. 750-A.D. 875	Tallahogan	Basketmaker III/ Pueblo I
A.D. 875-A.D. 975	Dinnebito	Pueblo I
A.D. 975-A.D. 1050	Wepo	Pueblo I/Pueblo II
A.D. 1050-A.D. 1075	Lamoki	Pueblo II
A.D. 1075-A.D. 1150	Toreva	Pueblo II/Pueblo III

surprising, given that most Archaic sites are open-air sites that exhibit few, if any, traits other than projectile points, truly diagnostic of the Archaic period. For example, a single San Jose point was found in the Chinle area (Lofton 1974); it may indicate use of the area by Archaic populations or it may have been brought in later from elsewhere. Generally there is no secure way to date a lithic scatter. A novel approach, for the area, was taken by the Glen Canyon project (Jennings 1966). Lithic sites tentatively were assigned the same date as the habitation site with which they shared a trail.

Concrete evidence of Archaic occupation comes from the Navajo Mountain area where several open twined sandals were radiocarbon dated between 5000 and 6000 B.C. The name Desha Complex has been assigned to these assemblages from Sand Dune and Dust Devil Caves in the Navajo Mountain area. Similar artifacts also have been found in the Glen Canyon area.

> Artifacts apparently diagnostic of this assemblage, and not found in later assemblages in the area, include open twined sandals, warp-faced sandals, elongate and shallowly side-notched projectile points, basketry with a one rod foundation and interlocking stitches, twined grass matting, a painted pebble, worked bobcat scapulas, and worked mountain sheep hyoids. Other artifacts associated with the above, but also found in later (particularly Basketmaker II) assemblages, include wider side-notched points; round and square based kives; shallow, basin grinding slabs; one-hand manos (typically wedge-shaped); fur; fiber and human hair cordage; bone awls; coal pendants; abalone shell ornaments; and a host of minor artifacts. Judging from the high percentage of small mammal bones, relative paucity of projectile points, and large numbers of grinding stones, the subsistence pattern was one of primary dependence on wild plant foods and small game, with large game being only occasionally utilized (Lindsay et al. 1968:120).

The only other good evidence of man's presence in or near the region is that of the split-willow twig figurines from the Grand Canyon which have been dated between 3,000 and 4,000 years ago (Euler and Chandler 1978). The figurines were found in caches in caves in the Mississippian Redwall Limestone Formation and have been hypothesized to have been produced by Pinto Basin populations for imitative magic. No additional evidence dating to this time has been found (although a few radiocarbon assays from otherwise Basketmaker II sites on Black Mesa date to this period).

Upon initial consideration it may appear odd that almost no Archaic sites have been found on Black Mesa; however, this has been explained by examining the naturally occurring foods the mesa has to offer. According to Ford et al. (1977:1), ". . . without reliance on animals or cultivated plants Black Mesa plant resources cannot sustain large human populations or sedentary communities."

Thus, although there is some evidence of these early populations in the area, it is very limited. Occurrences of this evidence have been too few and far between for meaningful interpretations of these past lifeways, possibly as a result of very low populations and/or only occasional use of the area.

Black Mesa Phase Sequence

The remainder of this section will present detailed descriptions of the Black Mesa phases: Lolomai, Dot Klish, Tallahogan, Dinnebito, Wepo, Lamoki, and Toreva. Each phase description will include information on ceramics, architecture, artifacts, subsistence-settlement patterns, and organization. Mean house size figures were calculated by the author from published excavation reports. Data from other areas within the Kayenta Anasazi region will supplement those for Black Mesa where appropriate. Because Black Mesa was the first of these areas to have been abandoned, the section will close by focusing on the latest part of the occupation sequence in each of the other areas.

Lolomai

The Lolomai phase is the equivalent of Basketmaker II in the Pecos Classification (Kidder 1927) and dates between 200 B.C. and A.D. 600 in the original Black Mesa phase sequence (see Table 2 for Pecos Classification equivalents to the Black Mesa phase sequence). However, dates on Basketmaker II sites excavated more recently extend the range back to 1200 B.C. In the Navajo Mountain area the terminal Basketmaker II date is extended to A.D. 700 (Lindsay et al. 1968).

On Black Mesa, a predominance of white baked siltstone in the lithic inventory is a good indication that a site dates to the Lolomai phase (Anderson 1977). Prior to identification of this pattern, it was believed that population density was very low as few sites had been recorded. However, this situation probably actually resulted from their being missed or misinterpreted as lithic scatters of undefined age (Klesert 1979a).

The heightened recognition of Lolomai sites also has served to change beliefs about site locations. Prior research found them mainly in close proximity to major washes (Karlstrom et al. 1976) but recent studies have recognized them in both lowland and upland sage areas. This altered perception of early site locations undermines, to some extent, the trend described in the original phase sequence from lowland floodwater to upland dry farming. This same trend was noted in the Glen Canyon area (Jennings 1966). It was believed to have been brought about by an amelioration of the climate and/or population pressure necessitating the settlement of new areas.

Evidence now indicates that corn was cultivated in both lowland and upland situations from the time of the earliest occupation of the mesa. Ultimately it may turn out that the original attraction held by Black Mesa was for farming. Corn occurs in all Lolomai habitation site deposits. Ford et al. (1977) described the mesa as lacking in wild resources, and Gregory (1916:69) found that "the Cretaceous strata--Dakota, Mancos and Mesaverde--contain a higher proportion of mineral plant foods than any of the other formations represented on the reservation. . . ." These are the uppermost strata on Black Mesa.

In fact, the earliest sites that have been found on the mesa (from the Lolomai phase) have large numbers of extramural hearths, which suggests that they may have been occupied mainly during the summer months when farming would have taken place (Klesert 1979a; Powell 1980). It is possible that people spent part of the year elsewhere utilizing other resources until agriculture comprised a sufficient proportion of the diet to allow year-around sedentary occupation of Black Mesa. One item of supporting evidence concerns Tsegi Canyon. This area's population was sparse at this time and, actually, up until the Tsegi Phase at A.D. 1250-1300. The low population has been attributed to the fact that the canyon was narrower than the broad valleys and thus was not as attractive for farming (Dean 1969). This area may have provided a winter home for the early Black Mesa inhabitants.

In Long House Valley at this time, rock shelters were used for habitation, storage, and burial, and probably functioned as semi-permanent base camps. Seasonal collecting and hunting camps were located on the Shonto Plateau. Few sites were located on the Black Mesa side of the valley; its pinyon-juniper woodland does not support as useful an understory of plants as does that of the Shonto Plateau. Unfortunately, no Basketmaker sites were located on the 1963-1964 survey of 15 km of roadway between Highway 64 (now 160) and Navajo National Monument headquarters (Anderson 1969).

In addition to corn, the diet of the earliest inhabitants of Black Mesa included a wider diversity of weedy plant species than that of the later periods (Cowan et al. 1978). Food items found in Basket-maker II cave burials in the region include Indian ricegrass seeds, pinyon nuts, squash seeds, and corn. Dog burials sometimes accompanied these burials (Guernsey and Kidder 1921; Colton 1939). The overwhelming majority of animal bone recovered from Black Mesa sites is cottontail and jackrabbit.

Pithouses were the earliest habitation units and averaged 3.7 m in diameter and 45 cm in depth. Pithouse walls were merely the original walls of the pit. Only rarely are support posts or internal features in evidence. Bell-shaped storage pits were the most common storage facili-ties in use during this period on Black Mesa. In cave sites (from the surrounding areas), which typically have shallow bedrock floors, deeply excavated structures were not practical and cists were employed instead. The caves were used mainly for burial and storage. Cists were of three types: (1) jar-shaped excavations, (2) larger, shallower pits for burials, and (3) slab-lined cists. Burials always were multiple, and typical grave goods included a tray basket and food items (Guernsey and Kidder 1921).

The layout and orientation of structures and features on these sites appears to have been "unplanned" when compared with the more formalized village plan evidenced at many later sites. The "planned" versus "unplanned" quality of the settlements has been suggested as representing differences in social organization. The "planned" unit pueblo common at Pueblo II sites is believed by some (Dean 1970; Aberle 1970) to represent localized lineages, whereas the "unplanned" type is believed by others (Birkedal 1976) to represent band-level organization with the nuclear family as the key unit (Klesert 1978). These assertions remain to be tested on the Black Mesa data.

One-hand manos were more frequent than two-hand manos, and both types were made from either sandstone or purple conglomerate. Chipped stone artifacts from Black Mesa were manufactured almost exclusively from locally available materials (i.e., baked siltstone and sandstone) for which sources are located in close proximity to the sites. Ceramics were not manufactured during this period. However, at cave 6, South Comb, Guernsey and Kidder (1921) found some sherds that looked like pottery. These were unfired and tempered with shredded cedar bark. On one side was the imprint of coiled basketry. They have been interpreted either as primitive pottery or leftovers from smearing the joints in a slab cist. Square-shouldered human pictographs, considered diagnostic of Basketmaker II, were found on a survey of the north rim of Black Mesa at D:7:618 (Three Fir Shelter) and D:7:619 (Leaning Fir Shelter) (Kim

Smiley, personal communication). Other material culture items considered diagnostic of this period, but not yet found on Black Mesa, include atlatls and square-toed sandals (Guernsey and Kidder 1921; Morss 1927; Colton 1939).

Dot Klish

The Dot Klish phase on Black Mesa dates from A.D. 600 to 750 and is considered the equivalent of Basketmaker III. The Basketmaker III period in Long House Valley extends from A.D. 550 to 850 (Dean et al. 1978) and may not have existed in the Navajo Mountain area where the Basketmaker II life-style may have lasted until A.D. 700 or later (Lindsay et al. 1968).

Radiocarbon dates on several of the Lolomai phase sites indicate occupation only until about A.D. 1. There appears to have been a hiatus in occupation on Black Mesa from about that time until A.D. 800, which encompasses the latter half of the Lolomai phase, all of the Dot Klish phase, and the early part of the Tallahogan phase. Three hypotheses have been advanced to explain the lack of sites in the Black Mesa study area dating to this period: (1) sites exist but have been buried under alluvium (Karlstrom et al. 1976); (2) the area was abandoned during this period (Ware 1976); and (3) Lino Black-on-gray, which is diagnostic of Basketmaker III sites elsewhere, may not have been used on Black Mesa (Klesert 1979a). The first explanation assumes that sites of this phase were located only in the lowlands or at least in areas where they might have been covered by alluvium. This assumption seems unwarranted because sites of preceding and subsequent phases also were located in upland areas where they would not have been buried. No evidence or argument as to why the area might have been abandoned during this period has been offered. Thus, explanation #2 cannot be disproved but at present is supported only by negative evidence. An explanation along the lines of #3 seems most acceptable at this time.

The painted ceramic inventory on Black Mesa may have begun with black-on-white types, thus rendering Basketmaker III (Dot Klish) sites on Black Mesa indistinguishable from Pueblo I (Dinnebito) sites (Klesert 1979a). An alternative to the last hypothesis holds that errors may have been made in distinguishing Lino Black-on-gray from Kana'a Black-on-white, which it closely resembles (Gumerman et al. 1972). Both types are painted, and the early white wares have coarse sand temper similar to that of the Lino series. Misclassification of Lino Black-on-gray as Kana'a Black-on-white would result in the erroneous placement of sites in the Pueblo I or Dinnebito phase (Shirley Powell, personal communication), thus creating the "absence" of Basketmaker III or Dot Klish phase sites and a dramatic population increase during the Dinnebito phase.

As no Dot Klish phase sites have been located in the lease areas, information presented on sites of this phase is derived from three sites excavated nearby, to the southwest of the study area (Ward 1976). The sites are located on low knolls on the floodplains of major washes or in duned areas whose water-retention properties render them desirable, respectively, for floodwater and dry farming techniques. Floodwater farming evidently was the norm elsewhere, as settlements in both the Glen Canyon and Long House Valley areas were on the valley floors. Special use sites were located on the edge of the floodplain and in upland areas (Jennings 1966; Dean et al. 1978).

Previous researchers believed there were increases in sedentism and population at this time, but these beliefs were based upon a supposed increase in dependence on cultivated foods (Gumerman and Euler 1976). At the time these ideas were formulated, information on the recently excavated Lolomai sites was not available. The new information may cause this line of thought to be modified somewhat but, in any event, the suppositions remain to be tested.

Pithouses constructed during this phase were not as variable in size as those of the Lolomai phase and averaged 3.4 m in diameter and 57 cm in depth. Interior features included ventilators in either the east or southeast wall, sandstone slab deflectors, and basin-shaped hearths, which sometimes were slab-lined. Walls again were those of the original pit, and floors were merely hard-packed sand. Wall and floor treatment was more variable in Klethla Valley, as some walls and/or floors were plastered, some floors were covered with imported clean white sand, and others were merely the walls and floor of the pit (Ambler and Olson 1977). Four to six primary roof-support posts were common, suggesting a roof composed of a rectangular plate over which horizontal timbers were placed. One Black Mesa pithouse had a wing or interior partition wall common among pithouses of this age in other areas of the Southwest, including the nearby Klethla Valley (Ambler and Olson 1977). Other significant differences are apparent in pithouse architecture between Black Mesa and Klethla Valley. Mean diameter of pithouses in the latter area is 6.0 m, as compared with 3.4 m for Black

Mesa. Three possible explanations for this variation exist: (1) organizational differences, (2) winter versus summer occupation (Powell 1980), and (3) ease of excavation in floodplain compared with mesa-top soils. Most Klethla Valley pithouses also have antechambers that would be useful in ingress and egress in cold weather.

Storage facilities were more varied than in the preceding period and included (1) bell-shaped pits, (2) subsurface oval and circular pits, some of which were slab-lined and others plastered, and (3) oval to subrectangular dwelling or storage units that were slab-lined or plastered below ground with masonry above ground. The masonry usually was minimally shaped sandstone slabs from one to five courses high. Jacal structures were present at two of the three sites, one of which was about 6.5 m square and internally divided by partitions into six rooms connected by interior passages. Trash areas generally were ill-defined. "In no instance was there a linear village orientation of contiguous storage cists, pithouses, and trash deposit as has been suggested as the classic 'type site' for Basketmaker III" (Gumerman et al. 1972:191).

Ceramics were exclusively Lino Gray and Lino Black-on-gray, some of which exhibits a yellowish cast, presumably from being fired by coal. Problems with ceramic classification also may arise with the plainwares, again causing Basketmaker III and Pueblo I sites to be confused. In the absence of painted ceramics, plain gray wares may be used to distinguish between Basketmaker III and Pueblo I sites; Lino Gray sherds generally represent Dot Klish (Basketmaker III) sites, and Kana'a Gray (neck banded) represents Dinnebito (Pueblo I) sites.

Problems may arise because the body sherds from the two types are indistinguishable (Beals et al. 1945) and should be classified as Lino Tradition rather than assuming that they represent one type or the other. Part of one intrusive Forestdale Smudged vessel was found at a Dot Klish phase site, indicating contact to the southeast.

Chipped stone raw materials recorded include various cherts, chalcedony, quartzite, jasper, petrified wood, and one basalt point fragment. The absence of local materials may reflect site location, a change in procurement strategy, and/or biased collection techniques on the parts of the archaeologists. Mano and metate types were divided between one- and two-hand and slab and trough, respectively. Materials were recorded as sandstone, but it is unclear whether purple conglomerate was included in this category.

Tallahogan

The Tallahogan phase (the transition between Basketmaker III and Pueblo I on Black Mesa) tentatively has been dated between A.D. 750 and 875. Only one site assigned to this phase has been excavated, and it was found deeply buried on the first terrace of Moenkopi Wash exposed in a water-pipe trench. Because of the heavy overburden, only the single exposed pithouse was investigated. It was oval-shaped (3.1 m east-west by 4.08 m north-south) and 95 cm deep. Walls and floor were plastered, and interior features included a slab-lined hearth, ash pit, and storage bin. Ceramic types were mainly Lino Tradition, either Lino Gray or Kana'a Gray (neck banded). Painted ceramics included Kana'a Black-on-white and Abajo Red-on-orange. Two-hand manos were slightly more frequent than one-hand manos, but sample sizes are so small that this may not be significant. Metate fragments were of the trough type.

It has been suggested that the Tallahogan phase be deleted from the phase sequence (Klesert 1979a) and that the time spans covered by the preceding Dot Klish and subsequent Dinnebito phases be increased to include the Tallahogan time span. The basis for this suggestion lies in the difficulty of ceramically separating the three phases and the paucity of sites whose occupation spans fall into this time period. Patterns outlined for this time period in other areas of the Kayenta region generally are the same as those for the two centuries preceding and for at least 25 years following its terminal date. Evidence is not abundant but generally indicates that floodwater farming was conducted from small pithouse settlements with special purpose sites in nearby upland areas (Jennings 1966; Dean et al. 1978).

Dinnebito

Dinnebito phase (Pueblo I) sites, which date from A.D. 875 to 975, are more numerous than those of preceding phases. Patterns exhibited during the earlier phases became more pronounced as more sites were located in the uplands, and, for the first time, some had surface masonry structures. However, excavations at several earlier sites in the uplands where corn agriculture was practiced may temper what was perceived as a change in settlement location to an increased tendency for upland use. This tendency toward greater use of the uplands appears most often in the form of special use sites, whereas more-permanent habitation sites were located near lowland washes (Klesert 1979a). This same pattern has been noted for the Glen Canyon (Jennings 1966), Navajo Mountain (Lindsay et al. 1968), and Long House Valley (Dean et al. 1978) areas. Changes in settlement location over time have not been noted for Monument Valley, where sites were either recurrently or continually occupied (Neely and Olson 1977).

Although masonry structures began to be constructed at some sites, pithouses still were the most common architectural type. They were smaller, but slightly deeper, than those of the preceding phases, with mean dimensions of 3.0 m by 2.4 m and a mean depth of 62 cm. Mean subterranean volume (excluding the single large Tallahogan pithouse) decreased from slightly over 6 m^3 to about 4.5 m^3. Exterior postholes that encircled some of the pits suggest that a jacal superstructure may have been built aboveground. Certain features such as benches and sipapus, usually used to identify kivas, have been found in some pithouses of this phase. Double ventilator shafts have been found in pithouses in the Hopi area (Daifuku 1961), along Laguna Creek (Gumerman and Skinner 1968), and possibly on Black Mesa (Layhe et al. 1976).

Storage facilities no longer were as varied as they had been earlier; some of the smaller pithouses that had no interior features (except storage pits) may have been used for storage. For example, of the 10 masonry rooms at D:7:134, a lowland site, only one had an internal hearth; another had two features of unknown function; and the rest had either no internal features or storage pits only, suggesting that they, too, may have been used for storage (Layhe et al. 1976). These rooms averaged 2.2 m long and 1.7 m wide, and masonry walls were an average of 56 cm above the floor. Three of the rooms may have had full masonry walls, while the rest may have had jacal superstructures. Masonry construction consisted of shaped or unshaped sandstone blocks and mortar. Jacal structures were present at four of six excavated sites. The presence of internal hearths in most of these rooms suggests that they were used for habitation. These rooms varied considerably in size from 2.0 m square to 9.5 by 4.0 m.

The vast majority of ceramics at these sites were of the Lino Tradition, either Lino Gray or Kana'a Gray. Kana'a Black-on-white was the most frequent painted type; extremely low frequencies of San Juan Red Ware and Tsegi Orange Ware were found at one site. The problems of ceramic classification mentioned earlier are not unique to Black Mesa. According to Jennings (1966:34),

> A defect in the original scheme (the Pecos Classification) is the nebulous character of Pueblo I and its limited distribution. Reed (1963b), in an attempt to clarify the significance of the Pueblo I stage, documents the imprecision or at least their non-exclusive occurrence of the traits ascribed to Pueblo I. Failure to find a Pueblo I period, in his words only means the ". . . absence or scarcity of banded necks on the grayware and of Kana'a style on the black-and-white."

Pueblo I sites are rare in the following areas: Navajo Mountain, Glen Canyon, and the Shonto Plateau.

Considerable variability in the abundance of chipped stone artifacts was noted between the upland sites located near the north rim of Black Mesa and lowland sites along Moenkopi Wash. The upland sites, with a relative abundance of chipped stone, are believed to reflect the same economic base as the lowland sites but to have had easier access to chipped stone raw materials from the valley below. Recent research supports the pattern for higher frequencies of nonlocal raw materials at sites with access to the valley (Borger 1979). However, another study suggests that the use of local materials at lowland sites may have gone unrecognized by earlier researchers and/or that chipped stone was not recorded uniformly at all sites (Green 1977, 1978).

Ground stone was described for only one Black Mesa site, D:11:1158; two-hand manos and trough metates were the only types found. These types were most common in the other areas as well.

Although rabbit bone continued to comprise the majority of the faunal remains, some larger mammals were found at both upland and lowland sites and include mule deer, pronghorn antelope, and possibly mountain sheep. The turkey evidently was domesticated by this time, as remains of turkeys and/or turkey pens were found on sites dating to this period from Black Mesa (Anderson 1978a) and Tsegi Canyon (Breternitz 1969). Evidence of turkey domestication and use from later time periods has been found on the Shonto Plateau (Anderson 1969), in the Chinle Valley (Morss 1927; Lofton 1974), and the Marsh Pass area (Kidder and Guernsey 1919).

Flotation analysis on samples from two Dinnebito phase sites indicates divergent economic pursuits within the upland area. At D:11:1153, flotation samples yielded seeds of goosefoot, Amaranthus sp., and Indian ricegrass, which suggest summer occupation unless the seeds had been stored for later consumption. A nearby site, D:11:338, had flotation samples that yielded mostly maize and very little chenopodium and amaranthus (Layhe 1977a; Anderson 1978b). These differences may represent different seasons of occupation, different subsistence emphases, or different "final use episodes."

Differences in site configuration are apparent among the lowland sites also. Where one site may exhibit the "standard Toreva phase format (masonry roomblock, kiva and trash going from northwest to southeast)" (Klesert 1979a:33), another nearby has no recognizable plan at all. This lack of consistency among sites generally has been considered characteristic of the Dinnebito phase and occurs among sites dating prior to A.D. 1050. Toward the end of the phase, when population began to increase dramatically, site configuration became more standardized.

An alternate interpretation for this perceived pattern is based upon the fact that after A.D. 1050 masonry rooms were more common on sites. It is known that the presence of masonry rooms on Black Mesa is a good indication that other room types also will be present (S. Plog 1977a). Early excavators on Black Mesa emphasized sites with masonry structures that resulted in their finding fairly standardized site layouts. Recent excavation without this emphasis has found much greater variation in site layout; thus the variation does not appear to be unique to the Dinnebito phase.

In his recent summary article on the Western Anasazi, Fred Plog (1979:115) pointed out that this stage is not very well understood even today: "This particular stage is not well known. Either sites are few in number or population was dispersed into small and widely separated sites. Moreover, the evidence from excavated sites of the period is diverse and disparate if not contradictory."

Wepo

The Wepo phase dates between A.D. 975 and 1050. During this phase the trend toward upland settlement on Black Mesa was amplified. Lindsay et al. (1968) noted that the upland areas were being used for permanent residence for the first time in the Navajo Mountain area. However, upland habitation sites occur throughout the phase sequence on Black Mesa.

A tendency for sites to cluster, which was only slight during the earlier phases on Black Mesa, became more pronounced in later periods. Architectural forms were more varied than at earlier sites and the usage of contiguous jacal units and surface masonry became more common. Jacals and pithouses still were used for habitation, with the latter also used for storage. Masonry rooms apparently continued in use primarily for storage, as the few excavated generally lack hearths and have only storage-related features.

Surface masonry structures never became important in the Klethla Valley where pithouses were the major residence form throughout the sequence. Reasons for this pattern may include the desire for relief from constant winds and the distance from which building stones would have to have been obtained (Ambler and Olson 1977). In the Chinle area adobe sometimes was used instead of masonry as a building material for the upper parts of walls with stone-slab foundations (Morss 1927). Taking the above statements into consideration, and adding the fact that on Black Mesa jacals were used more frequently than in most other areas, architectural patterns on habitation sites generally were similar across the Kayenta region.

> Sites of this period, as represented by Small Jar Pueblo, are usually the front-oriented unit pueblos consisting of a small room block of jacal-built living and storage units, an adjoining work area, a fully subterranean circular kiva and beyond the structures a trash area. Subterranean pits were probably used as granaries (Lindsay et al. 1968:364).

Masonry generally was of the Kayenta style, which consists of undressed, irregular stones held together by the generous use of mortar.

Pithouse shapes were quite variable, even within a single site, and included circular, oval, D-shaped, subrectangular, and rectangular shapes. Pithouses that functioned as habitations were larger than those of the Lolomai and Dot Klish phases but were about twice as large volumetrically as those of the Dinnebito phase, with mean dimensions of 3.2 m east-west, 3.6 m north-south, and 78 cm in depth. (The Dinnebito pithouse dwellings actually may have been as large as those of the three surrounding phases, but the inclusion of pithouse storage facilities in the calculations may have lowered the mean.) In most instances, evidence of postholes encircling the pithouse suggests a superstructure of jacal, which was observed at earlier sites also. Although plastering of walls and floors occurred at some sites, it was not a common practice.

Kivas became more common and kiva feature associations became more formalized during this period. The features included hearths, ash pits, sipapus, ventilators, deflectors, foot drums, ladder holes, and three-quarter and full benches. Kivas averaged 5.5 m east-west, 5.1 m north-south, and 168 cm deep. Trash areas were more well defined at Wepo phase than at earlier sites.

The most common ceramic types were Lino Tradition, including Kana'a Gray and Lino Gray; and Kana'a, Black Mesa, and Wepo Black-on-white. Less common ceramics were San Juan Red Ware, Tsegi Orange Ware, and Deadman's Gray, a Cohonina type indicating contact to the west.

Chipped stone raw materials included cherts, quartzite, petrified wood, sandstone, iron concretions, and small amounts of basalt and obsidian. The same pattern of abundance of lithics at sites near the north rim recognized for the Dinnebito phase is apparent at Wepo phase sites also. Two-hand manos and trough metates were the most common ground stone types, but one-hand manos and slab metates also were in evidence.

Flotation analysis was performed on samples from two upland Wepo sites. At D:11:814 only a few goosefoot seeds were found, but at D:11:1084, although wild plant foods including Indian ricegrass, pinyon pine cone scales, goosefoot, amaranthus, and juniper seeds were in the majority, small amounts of corn also were recovered. At two other sites only macrofloral evidence was reported. A D:7:11, a site on the Black Mesa bench, macrofloral remains included corncobs and cupules, and at D:11:18 corncobs and juniper seeds were present. Animal bone, some of which occurred in the form of artifacts, included rabbit, mule deer, antelope, bighorn sheep, and turkey.

Standing Fall House, the 55 room cliff dwelling in the north, was under construction at this time. The site is located near the only known spring in the northern part of the mesa but is out of the study area proper. It has 33 granaries, 14 masonry habitation rooms (which also could have been used for storage), two kivas, five courtyards, and one unidentifiable room (Klesert and Cowan 1978). Although it seems to have had a long occupation (A.D. 971 to A.D. 1058), the midden has a surprising lack of accumulation. It seems to have been used mainly for storage and redistribution rather than habitation (Klesert 1979b). F. Plog (Martin and Plog 1973:356) suggested that Cliff Palace at Mesa Verde may have served a similar function, and Promontory Ruin in the Chinle area also fits the same description. "Either the population consisted largely of men, who lived in the kivas or, as seems more probable, Promontory Ruin was a storehouse, refuge, and ceremonial center for all the inhabitants of the canyon" (Morss 1927:28). Turkeys apparently were raised there (Morss 1927; Lofton 1974). Thus, the settlement pattern for at least part of the region may have included small dispersed settlements with a larger integrating site used primarily for ceremony and storage.

Lamoki and Toreva

The Lamoki and Toreva phases, which date to A.D. 1050-1075 and A.D. 1075-1150, respectively, will be discussed together due to the extremely short time span of the former, which would make comparisons with neighboring areas very difficult. The suggestion has been made to extend its range to A.D. 1100, for reasons that will be discussed below (Klesert 1979a). Population apparently continued to increase during this period, as attested to by the increasing number of sites. In addition, there were a few sites larger than those typical of earlier phases. Dramatic population increases have been noted for Glen Canyon, Long House Valley, the Shonto Plateau, and Navajo Mountain during this period.

The intersite diversity in resource procurement noted during the earlier periods became more restricted during the Lamoki and early Toreva phases (S. Plog 1978a). These sites all have high frequencies of cultivated foods. In other areas, intensification of agriculture occurred and is evidenced partially by the appearance of water/soil control features. Changes in subsistence are observable after about A.D. 1100 on Black Mesa, and it is for this reason, as well as the fact that many site occupation spans seem to terminate at about A.D. 1100, that the suggestion to extend the terminal Lamoki phase date to A.D. 1100 has been made (Klesert 1979a).

In most of the surrounding areas (except the Klethla Valley, where the pithouse prevailed), site configurations were similar to those of the preceding Wepo phase. Habitation sites that probably housed small, fairly self-sufficient family units were widespread. Sites were located primarily with regard to arable land. On Black Mesa, more sites were located along secondary washes, in upland areas where it is presumed that dry farming took place.

Two types of village plans were common. On mesa tops, masonry rooms, jacal structures, and pithouses often were built around a common plaza. At cliff sites, a living room, one to six storage rooms, and a mealing room generally shared a common courtyard. A small site might have had a single courtyard complex that usually was built as a unit, and a large one would have had several (F. Plog 1979). Kivas usually were associated with plazas, but not with each individual courtyard because the social unit, probably a nuclear or small extended family, would have been too small to have warranted its own ceremonial structure.

Site configuration on Black Mesa became more formalized during this phase, often exhibiting the northwest-to-southeast layout of masonry roomblock, kiva, and midden. Numbers of masonry storage rooms at sites increased and, as noted by S. Plog (1978a), sites with masonry rooms tend to have larger kivas than those without. This suggests that these kivas served a larger population than that residing at the site. Entire villages on Black Mesa, which always were small, were equivalent to single courtyard groups. As mentioned above, several sites may have been served by a single kiva.

In the Chinle area, although one site with a plaza has been reported (Lofton 1974), the typical site differed from the unit-type pueblo in that it had no specific orientation and never was built with wings around a court. When the pueblo became too long, another was built nearby. No kivas were found at open sites there (Morss 1927).

The majority of sites located on the Shonto Plateau survey date to this time period (Anderson 1969). The basic pattern is similar to that described above, but a single small site deserves special mention. At this site, NA 8604, the only structures were a kiva and a small circular subterranean room with no internal features. Artifacts were sparse and there was almost a complete lack of domestic items. This was the only site on this survey that had trade sherds from the Mesa Verde area. NA 8171, a small site with only a kiva and storage pit, was excavated in the Cow Springs area and, based upon sherd counts, dates to late Pueblo II times (Ambler and Olson 1977). These sites evidently were used only for ceremonial and storage purposes (Anderson 1969) and, on a smaller scale, are similar to Standing Fall House, Promontory Ruin, and Cliff Palace, which were discussed earlier.

Some rather substantial changes in the sizes and functions of architectural features took place during this 100 year period on Black Mesa. Masonry rooms, which were fairly common on Lamoki phase sites, averaging 3.1 m by 2.0 m in size, became less common during the Toreva phase (they were at only one-third of the sites). However, their mean dimensions increased to 3.3 m by 2.0 m. In addition, some of these rooms were used for habitation (as evidenced by internal hearths) rather than having been used for storage. Bell-shaped storage pits increased in frequency, apparently as replacements for the dwindling numbers of masonry storage rooms. Jacal structures were the most frequent type found at Lamoki phase sites, with mean dimensions of 5.2 m by 4.0 m. These decreased in size (to 3.6 m by 2.7 m) and, in some cases, were used for storage. Pithouse habitation rooms no longer were very common. Most of them were rectangular, and they decreased in size from 3.5 m by 2.9 m to 2.4 m by 2.1 m. The average size of mealing pithouses, however, increased slightly from 2.7 m by 2.0 m to 2.9 m by 2.4 m. Jacal structures sometimes were used as mealing rooms also. Kivas became more common during the Lamoki phase and, with the exception of an unusually small one at D:11:97 (3.0 m in diameter), the mean diameter, slightly over 5.0 m, was comparable to that of the preceding Wepo phase kivas. Although kivas still were fairly common in the Toreva phase, they decreased in size to about 4.1 m in diameter. In addition to these structural remains, evidence of encircling walls was present at several Lamoki and Toreva phase sites.

Only three of 12 Toreva phase sites evidenced the formalized village pattern that used to be ascribed to this phase with roomblock, kiva, and midden in a northwest-southeast line. Two of the three sites were in the lowlands, and the third, upland site, dates to the early part of the phase. It probably would fall within the proposed extended Lamoki phase boundary, when this pattern actually may have been more common. Sites dating to the Toreva phase appear to have had short occupation spans with little evidence of more than one building episode.

The most common painted ceramic type at these sites is Black Mesa/Sosi Black-on-white. Lower frequencies of Black Mesa, Sosi, Dogoszhi, Wepo, and Flagstaff Black-on-white were present at some sites. Gray wares generally included high proportions of Tusayan Corrugated and Moenkopi Corrugated. Red wares also were found at some sites.

Chipped stone raw materials included high frequencies of various cherts (especially among the utilized artifacts) and lesser amounts of local materials, including petrified wood, siderite, sandstone, and baked siltstone. Two-hand manos continued as the predominant mano type, and slab and trough metates were the most common metate types, with the latter in slightly higher frequencies.

Corn, which was recovered at all Lamoki phase sites, was found at most, but not all, of the Toreva phase sites. Gathered plant food remains were abundant and diverse at almost all Toreva phase sites. The most abundant animal remains at the few sites analyzed from the Lamoki phase are those of the desert cottontail. Following far behind are mountain sheep, jackrabbits, gophers, and woodrats. Dog, coyote or wolf, and bobcat remains contributed very low percentages to the total assemblage. Animal remains from the Toreva phase appear to have been the same as from the earlier periods.

The evidence (i.e., decreased storage space, less formal site configuration, greater emphasis on wild food resources, and shorter site occupation spans) points to the disintegration of the earlier patterns and leads up to the abandonment that occurred by the end of the Toreva phase, A.D. 1150. A detailed discussion of the alternative explanations that have been offered for the causes of the abandonment will be provided in the chapter on culture change models.

Rather than continue this section with separate discussions of the subsequent Klethla and Tsegi phases, a short description of the final cultural manifestations in each of the areas will be presented.

Although they stated that the description probably is too simplistic, Neely and Olson (1977) found that the social units in the Monument Valley area, throughout the occupation sequence, were small, localized family units. A Hopi-like farming strategy was employed, and abandonment has been linked with the erosional cycle. By A.D. 1250 the area was abandoned (although some sites later were reoccupied) and it is believed that the people migrated to Tsegi Canyon and the Hopi Mesa-Jeddito Valley area.

The latest sites found on the Shonto Plateau survey indicate that use of the area had diminished by A.D. 1200. These include a single masonry storage structure, a campsite with hearths that may have functioned as a quartzite quarry, and a single female burial in a trash deposit. Ceramics at these three sites included Tusayan and Moenkopi Corrugated; Flagstaff, Sosi-Dogoszhi, and Tusayan Black-on-whites; Tusayan Polychrome; and lesser frequencies of several other types. The area apparently was abandoned by A.D. 1250 (Anderson 1969).

Although population in the Klethla Valley was decreasing at this time, there still is evidence of occupation there in the form of several subterranean rectangular pithouses. One had a ramp entry shaped like a long rectangle. Walls and floors often were plastered. A small, nearly circular kiva of 3.7 m in diameter was found, in addition to a circular mealing room. Ceramic types included Tusayan Black-on-red, Dogoszhi variety; Tusayan Polychrome; Black Mesa/Sosi Black-on-white; Kayenta Black-on-white; and Tusayan Black-on-white. By A.D. 1300, the area was abandoned (Ambler and Olson 1977).

Several of the later sites in the Chinle area had two stories, and there were plaza-oriented sites. A keyhole-shaped kiva at one site indicates contact with Mesa Verde, which, according to ceramic evidence, was strongest between A.D. 1000 and 1100. This area, also, was abandoned by A.D. 1300 (Lofton 1974).

Jennings (1966) discussed at some length the fact that over much of the Kayenta Anasazi area sites remained small throughout the entire sequence. Glen Canyon seems to have been one such area.

> Most architectural forms in Glen Canyon and the tributaries are for food storage; few dwellings were found. For this lack of human housing there are two clear reasons. First in time there is the fact, beautifully documented in Lake and Moqui canyons, that many—perhaps most—of the dwellings are deeply buried and were not even

> visible to our surveyors. The little villages must have occurred wherever there was enough fertile fill to permit crops. A contrary explanation has been offered that the canyon dwellers were a succession of farmers who did not dwell in permanent houses or who were even summer visitors. The point is not likely to be clarified now because of the second factor which is simply that most of the tributary canyons have been flushed out; the remains of the Pueblo houses of A.D. 900-1200 have gone down the Colorado, leaving only high alcove granaries or crude storage rooms and, rarely, a well-defined dwelling (Jennings 1966:62).

The changes that took place in Long House Valley and Tsegi Canyon at this time have been studied in greater detail than most of the rest of the areas. The Black Mesa side of the valley was depopulated, except for a few limited activity sites on the Black Mesa bench. The locus of farming shifted to the northwest side of the valley on Navajo Sandstone-derived soils. Unit pueblos persisted but were more complex and larger than previously. Some larger pueblos were organized around a central plaza. Total population probably was the same, but during the period from A.D. 1150 to 1250, population density was higher than for earlier periods. After this time, habitation was concentrated even more onto the dunes in the northwestern part of the valley with sites no longer in the upland sage areas. Large habitation sites of both the plaza and nonplaza types were grouped into five clusters, four on the valley floor and one at the confluence of Long House Valley and Laguna Creek. These clusters were distributed around a central site that had long roomblocks of cored, double-faced masonry, plazas with or without kivas, and, in four out of five cases, reservoirs for water storage. Population increased from A.D. 1250 to 1300, partly because of the immigration that may have been caused by a desire to move up Laguna Creek ahead of the arroyo-cutting process. Although no sites dating after A.D. 1250 were found on the Shonto Plateau survey, it is believed that limited activity sites related to the sites in Long House Valley were located there until the area was abandoned at about A.D. 1300 (Dean et al. 1978; Effland 1979).

Tsegi Canyon was one of the last places in the region to be densely populated. This may be related to the narrowness of the canyon, which made it less desirable for farming than the valley floors; it was one of the last places to which people moved before they left the area entirely. Tsegi Canyon is upstream along Laguna Creek and thus would have been one of the last places to be affected by the erosional cycle that culminated in a fully developed arroyo system by A.D. 1300. All sites during the Tsegi phase (A.D. 1250-1300) were built either in caves or on eminences above the valley floor, possibly to avoid the arroyo cutting. Immigration into the area apparently came in waves (over the period from A.D. 1250 to 1272) as evidenced by tree-ring dates from construction activities. Building sequence analysis has demonstrated that people who inhabited Kiet Siel Pueblo came and left as household units, whereas Betatakin evidently was settled basically at once by a previously existing community.

Rooms occurred in clusters, usually with one living room, from one to four storage rooms, and a courtyard. In cave-site masonry rooms, more mortar than stone was employed, in effect to "glue" the structure to the cave wall. At open sites, the reverse was true. Jacal walls usually were used for only one or two walls of a structure due to the difficulty of sinking posts into a bedrock floor.

The entrybox complex, which links the door and the deflector, is considered diagnostic of Pueblo III. In Tsegi Canyon, if the room wall was masonry the deflector also was built of masonry; if it was jacal, a slab deflector was employed. Rooms with roof entries and no door did not have entryboxes.

Kivas at Tsegi phase sites fall within the range of variation of other Kayenta Pueblo III kivas. The range of variability includes circular, oval, rectangular, and keyhole outlines; presence or absence of a bench; roof entry; firepit, ventilator-deflector complex; loom anchors; wall niches; sipapus; pilasters and rock-paved floors. Grinding rooms in cave sites often were not roofed, and here, as at Navajo Mountain sites, bins and metates were destroyed at abandonment.

There were no spatially defined blocks of rooms with associated kivas that might represent localized lineages at Tsegi phase sites. If there were lineages, they must have been nonlocalized as among the Hopi. This differs from the pattern seen in the Navajo Mountain area, to be described below. Jennings (1966) believed the Tsegi phase social organization was nothing more than ties of familiarity and friendship. Dean (1969) disagreed and pointed to resemblances with the Hopi villages, which have a formally structured pattern but no formalized intervillage contacts. Population peaked at about A.D. 1285 but had declined rapidly by A.D. 1300, which means that none of these villages was occupied for more than 50 years.

From A.D. 1200 to 1250 villages in the Navajo Mountain area grew, as did population on the Rainbow Plateau. They increasingly were built on eminences at margins of arable land, and tied in with this and the fact that settlements moved upstream was, in all likelihood, the erosional cycle. Farming in the lowland localities was reduced greatly after A.D. 1225. Settlements mainly were 10 to 40 rooms and more, but they were spaced farther apart than during early and middle Pueblo III. Villages typically were at some distance from arable land. In addition to masonry and jacal structures, there still were a few semisubterranean pithouses for habitations. Both plaza- and courtyard-oriented large villages were present in the area. The plaza sites consisted of masonry rooms or pithouses oriented around at least three sides of a plaza that had one or more kivas. They had no recognizable room clusters. Dean (1969) suggested that this represented a localized lineage and that if this form persisted while the nonlocalized lineage was developing it must mean that more stable population conditions obtained in this area than in others. By A.D. 1270, population was leaving, possibly for Navajo Canyon or Tsegi Canyon. By A.D. 1300 the area was abandoned.

Culture History Summary

No evidence of Paleo-Indian occupation and only limited evidence of Archaic occupation, the period during which the Kayenta region was first inhabited, has been found on Black Mesa. Diagnostic projectile points suggest Paleo-Indian use of other parts of the region, and remains dating to the Archaic period have been found at Navajo Mountain and in the Grand Canyon.

It has been suggested that farming potential rather than wild resources was the major attraction held by Black Mesa. The earliest occupants practiced corn agriculture in both the lowland and upland areas. However, wild resources were a major component of the diet, at least up until and following the Lamoki and early Toreva phases, if not throughout the entire sequence. High frequencies of cultivated foods were found on sites dating to the Lamoki and early Toreva phases, rather than the usual diversity of foods. Agriculture apparently was intensified in other areas, at this time, as attested by increases in the numbers of water/soil control features. After this period, during the late Toreva phase, there was a reversion to high frequencies of gathered plant foods.

The trend in subsistence is reflected also in the storage facilities found on sites. During the earliest periods when weedy plant species, in addition to corn, formed the main part of the diet, and it is questionable whether sites were occupied the year-around, bell-shaped pits were the principal storage features. Storage facilities became more numerous and diversified prior to the advent of masonry storage rooms. At the very end of the sequence, room functions were not quite as well defined as they had been earlier. Some masonry rooms were used for habitation, and jacal structures, the easiest to build, were used not only for habitation but for storage and mealing as well.

Pithouses were the most common form of habitation room through the Pueblo I period. After this time, jacal structures were very common on Black Mesa sites and usually flanked the masonry storage rooms when they were present. The replacement of pit structures by contiguous surface rooms usually is attributed to an increase in population size and the need for a more compact room layout (Martin and Plog 1973). Even though population did increase over time, site size on Black

Mesa never reached proportions that should have prompted such a shift. This change never did occur in the Klethla Valley. More probable causes of the shift are increasing permanence of site occupation that may be linked to ability to perform regular repairs and/or a shift in climatic regime that made pit structures impractical in periods of heavy rainfall.

Pithouses with kiva features appeared on sites during the same period as surface masonry storage rooms. Kivas became more formalized as masonry structures increased in frequency, sites began to cluster, and two-hand manos and trough metates became the principal ground stone types. These all have been taken as indications of increasing dependence on cultivated foods, which, when relied upon heavily, may have made existence on the mesa more precarious. Kivas at sites with masonry storage rooms were larger than at those without and apparently served an integrative function. Single large integrative centers were found in several areas of the region. Concomitant with and possibly causing the more formalized integrative mechanisms was an increase in population and an increasing tendency to utilize upland areas, first primarily for limited activities and later for year-around habitations. This upland trend may have been a response to population pressure or a move upstream away from the main washes, which were becoming channelized during a period of severe arroyo cutting.

It is apparent that at the end of the sequence, just prior to abandonment, the shift toward increasing dependence on agriculture, during the Lamoki and early Toreva phases, and more formalized village plans disintegrated. Very few late villages had formalized layouts, wild plant foods were relied upon more heavily, and jacal structures, which required the smallest labor investment, were used for a wider variety of functions than previously. Although not all areas within the Kayenta region were abandoned at the same time, and many of the particulars described here do not pertain to all of them (as indicated within the preceding section), the general pattern does appear to obtain throughout the area. The hypothesized causes for some of the patterns outlined above will be presented in greater detail in the following chapter on Culture Change Models.

CHAPTER III

CULTURE CHANGE MODELS

Introduction

Interaction is the focus of this study. Prehistoric interaction is viewed here as equivalent to Firth's use of social organization:

> The structure provides a framework for interaction. But circumstances provide always new combinations of factors. Fresh choices open, fresh decisions have to be made, and the results affect the social action of other people in a ripple movement which may go far before it is spent. Usually this takes place within the structural framework, but it may carry action right outside it. If such departure from the structure tends to be permanent, we have one form of social change (Firth 1964:35).

The distribution of the various nonlocal raw material types across sites on Black Mesa is, to some extent, a product of interaction or social organization, through information exchange, material exchange, and/or extension of rights of access. Material acquisition may have proceeded within institutionalized exchange spheres or may have resulted from happenstance either consistent with the usual channels or outside them. Whatever the case, it is assumed for the purposes of this study that raw material procurement networks were constant enough to have left perceivable patterning in the archaeological record. It is believed that this patterning should be consistent with the larger social organization and, as such, should provide a useful material referent for it. (See Chapter I for discussion of the relative merits of chipped stone versus ceramics in this type of analysis.)

In a recent article, Braun and Plog (1980) have drawn together a number of ideas about how organization changes--in particular, how regional social networks develop. They feel that adaptive responses are geared to "environmental variability, risk, or uncertainty" (Braun and Plog 1980:6), primarily caused by the unpredictability of the environment over space and/or time and the diversity of environmental properties with which any living system has to interact. (The environment includes not only the physical, but the social environment as well.) Social organization, in this model, is viewed as a hierarchy of responses to environmental uncertainty (which can be combined with Firth's usage presented above). Uncertainty that is short-lived produces short-term responses; more permanent environmental uncertainty produces more regular responses.

For example, some authors (Whallon 1968; Leone 1968) have postulated that increased dependence upon agriculture should produce more autonomous communities. Braun and Plog believe the opposite to be the case. Although

> reliance on agriculture is an attempt to even out fluctuations in the resource base and decrease search and pursuit time by providing an aggregated resource whose energy output can be reasonably anticipated, barring a disaster, and stored for some time (Shelberg 1980:426)

there are greater risks involved in depending upon this source of food. These increased risks derive from the simplification of the ecosystem (replacing varied wild vegetation with a single or limited number of domesticated species) and depending on fewer species, which has the potential to make environmental fluctuations more critical. Braun and

Plog argue that, rather than greater autonomy, increased dependence upon agriculture (or any situation of increased environmental uncertainty) will generate increased cooperation. Other factors that might increase environmental uncertainty include increased population density with resulting decreased mobility and, of course, detrimental climatic change. Whatever the cause, a situation of resource uncertainty would arise in which people vie for the same resources whether they are in the form of superior agricultural lands or wild plants and animals. Environmental uncertainty would have an affect not only on organization; it might also, for example, effect changes in production modes, site locations, and reproductive fertility (Braun and Plog 1980).

Cohen (1977) outlined 14 ways in which strain in adaptation to the environment can be recognized, including "spread of settlement into new ecological zones, concentration on previously ignored microniches, a move from dependence on large to dependence on small wild animal resources, environmental degradation due to man, and decreases in the sizes of shells and domesticated animals" (Hodder 1979:449). Evidence for the above indications of strain (excluding the final one) will be presented in support of the Braun and Plog model for increased interaction with increasing environmental uncertainty. The models that follow should be viewed from the perspective of this overarching model and have been evaluated with it in mind.

Several aspects of culture change have received the bulk of attention in the generation of culture change models for the Black Mesa area. These are: (1) population increase that occurred throughout the sequence, but which was most dramatic on Black Mesa between A.D. 1000 and 1100; (2) changes in settlement pattern; (3) increasing reliance on cultivated foods; and (4) abandonment of northern Black Mesa by A.D. 1150 and most of the rest of the Kayenta Anasazi region by A.D. 1250-1300. Several studies of these changes emphasized a single variable, generally population growth (Swedlund and Sessions 1976) or climate (Dean 1969; Karlstrom et al. 1976; Dean et al. 1978; Euler et al. 1979) as the prime mover. Others incorporated a variety of variables such as population growth, climate, and organization (S. Plog 1977a; Nelson 1978; Powell 1980). Most of the research upon which these models are based has been conducted on Black Mesa. Although many sites have been recorded from other areas within the Kayenta Anasazi region, most of the reports on them have been descriptive in nature. The models may apply equally well to other areas within the region, and they will be included in the following section where data are available. However, the focus of the section will be on the research conducted on Black Mesa. In the summary for this chapter, a model of interaction, as it changed in the Black Mesa region, will be outlined and used for generation of the hypothesis to be tested using the lithic raw material data.

Population Growth and Depletion of Resources

Swedlund and Sessions (1976) traced population growth and decline for Black Mesa primarily using survey data supplemented by excavation data from Peabody Coal's western lease area. In addition to identifying sequences of growth and decline, they also sought to determine whether one could account for the large population increase apparent by A.D. 1100 by internal growth alone or whether immigration had occurred. The relationship of population growth to the eventual abandonment of the study area also was explored. Relative rather than absolute growth figures were employed in the analysis by counting habitation rooms in excavated sites and extrapolating to sites for which only surface data have been obtained (survey sites). They assumed that their sample of sites was representative of all sites in all phases on northeastern Black Mesa and that sites all were single component and of short duration. These assumptions have been questioned by later researchers and will be discussed below.

The average annual population increase was found to be .86%, which was determined a reasonable internal growth rate by comparison with ethnographic studies. Jennings (1966) also believed that the apparent increases in population for the Glen Canyon region (which occurred predominantly during Pueblo II times) were a result of in situ population growth rather than migration.

The reconstruction of the cultural sequence on Black Mesa by Swedlund and Sessions (1976) is as follows: Early populations had a relatively new resource base, intensive agriculture, and they chose for settlement lowland areas near major washes that were amenable to floodwater farming. Hunting also was widely practiced. Gradually this reliance on agriculture allowed a more settled life that was conducive to population growth (Binford 1968). By A.D. 1050 the effects of population growth were felt, and new (upland) areas were inhabited as population density in old areas increased and old areas became depleted of resources (recall Cohen's evidence for strain). By A.D. 1125, more marginal areas were settled. By A.D. 1150, population growth, depletion of resources, and "other external factors" (which are undefined) led to the abandonment of the area. Swedlund and Sessions basically argued that the population exceeded the carrying capacity of the available resources, and the people had to leave. Similar models (with somewhat different time frames) have been presented for Navajo Mountain (Lindsay et al. 1968) and Glen Canyon (Jennings 1966).

Recent research (Catlin 1978; Moore 1978) has explored more fully the potential for the resource-depletion component of the Swedlund and Sessions model. Catlin (1978) assumed, for the purposes of his research on the locations of habitation versus limited activity sites, that sagebrush had invaded what once were grasslands on Black Mesa. This assumption, although not critical to his analysis, helps support his argument that these areas once were desirable for agriculture. Sage flats are not as suitable for agriculture as grasslands because sagebrush depletes soil moisture and nutrients. Catlin's assumption is based upon studies conducted elsewhere in the Southwest that indicate that sagebrush is an invader plant tending to colonize disturbed grasslands (Johnson and Payne 1968; Castetter 1957). More specifically, in the Glen Canyon region, "sage is seen as subclimax vegetation having taken over a garden plot after its abandonment" (Jennings 1966:48).

Consequences of a sagebrush invasion of grasslands cum agricultural fields would have been severe for prehistoric populations. Not only would agricultural potential of the land have decreased, but economically important grasses no longer would have been readily available in times of crop failure. Reversion to a hunting-and-gathering economy thus would have been increasingly difficult as more land was cleared for agriculture.

Moore (1978) tested Catlin's assumption of human-induced environmental degradation using flotation samples from Black Mesa sites, expecting to find an increase in the sage community and a concomitant decrease in grasses. Although she found an increase in sage frequencies following a large population increase (and presumably an intensification of agriculture), grasses were not found to decline in presence/absence terms. However, Moore failed to consider the fact that grasses, which are economically desirable, may have been sought from farther afield than sagebrush. The sagebrush may have been intruding nearby, as suggested by the increase in frequency. Although Moore's analysis does not support Catlin's assumption, it cannot be used to refute it either.

The analysis by Swedlund and Sessions was criticized by Layhe (1977b), who approached the same problem in a different manner and used data from Peabody Coal's eastern lease area survey and excavations. It should be noted that the eastern lease area survey covered a contiguous 130 km^2 area, whereas the sample of the western lease area was chosen by proposed coal strip mine areas and therefore does not stand as a statistically random sample.

Layhe questioned the assumption made by Swedlund and Sessions that household size was constant throughout the sequence and argued that if this figure had changed, the shape of the population curve would differ. He found the dating of sites from each phase to the phase midpoint a dubious procedure that assumes contemporaneity of all sites from the phase. He questioned the dating of the sites and the representativeness of the sample of sites due to the less than optimal sampling procedures. He concluded his criticisms by saying that the number of sites per phase may represent changes, not only in population but in organization and subsistence strategies as well.

Instead of number of habitation rooms on sites, Layhe used floor area of habitation rooms as his dependent variable, and site area and artifact density as independent variables. He used only single-component sites in his analysis, arguing that it would be too difficult to try to separate components to calculate the necessary variable values.

Layhe used multiple linear regression analysis to predict habitation floor area from site area and artifact density on excavated sites. The formula derived then was used to predict habitation floor area on survey sites. The predicted habitation floor areas were not accurate estimates of actual habitation floor area. However, the regression line did serve to distinguish fairly accurately between early and late sites. More reliable regression equations were achieved when these site groups were considered separately, but sample sizes were very low. Dates were assigned to survey sites using a multiple regression equation that was developed by predicting the latest tree-ring dates at excavated sites using certain ceramic percentages at the sites as independent variables. Relative population size for 25 year intervals was calculated by summing the predicted habitation floor area measurements for sites dating to particular intervals.

The resultant population curve is similar to the one generated by Swedlund and Sessions but shows some divergences. The population peak differs somewhat from the A.D. 1100-1125 peak in the Swedlund and Sessions model to A.D. 1050-1074 in the Layhe model. In addition, the Swedlund and Sessions model traced a constant increase in population, whereas Layhe found several stages of growth. S. Plog's (1978b) deviation-amplification model, to be discussed later, points to these stages of growth as evidence that population equilibrium never was reached on Black Mesa.

Population decline was slower, according to Layhe, beginning about A.D. 1074 and continuing until complete abandonment around A.D. 1150. John Ware (personal communication to Layhe) suggested that the earlier decline in population in the eastern lease area and slightly later population peak in the western lease area may reflect small-scale movements from the eastern to western lease areas.

There are certain potentially critical problems with Layhe's method of dating the sites. The standard error of the estimate for each date is ± 50 years; therefore, grouping the sites into 25 year periods is tenuous at best (A. Olshan, personal communication). Increased sample sizes, when available, may serve to support or alter these population growth estimates.

Environmental Change

Karlstrom et al. (1976) and Euler et al. (1979) intensively studied hydrologic patterns in conjunction with dendroclimatic and palynological reconstructions in order to view culture history in the context of environmental changes. A hydrologic curve was derived from stratigraphic data that considered relative temporal positions of nondepositional and intervening aggradational intervals. The latter were considered times of "increased hydrologic competence, higher water-table levels, and thus presumably more mesic climates" (Karlstrom et al. 1976:157). The pollen curve was found to parallel the hydrologic curve, indicating that pinyon pine pollen production was favored relative to juniper pollen in periods of more mesic climate.

Ceramically and tree-ring dated phase boundaries were found to be correlated closely with radiocarbon dated climatic oscillations toward drought conditions. Data from early phase sites (Lolomai and Dot Klish) on Black Mesa were not available at the time of their original analysis. Tallahogan and Dinnebito phase sites found prior to their study were located most often along the floodplains of major washes. This may reflect a desire to locate in close proximity to more secure water sources during times of drought in the eighth and ninth centuries A.D. After this time, climatic conditions became more favorable and the growing population increasingly used upland dry farming areas away from major washes. The crest of a mesic cycle occurred at A.D. 1100 during the Toreva phase when population was at its peak (under the Swedlund and Sessions 1976 model). After this time, the climate became drier and the population began to leave Black Mesa (Karlstrom et al. 1976).

Dean (1969) also leaned toward environmental explanations for population movement in the Kayenta region. He explained the sparse population in the Tsegi Canyon area, early in the sequence, as a result of the relative narrowness of the canyon, suggesting that the broad valley floors elsewhere would have provided more suitable farmland. Migration there in the thirteenth century is explained as a reaction to arroyo cutting elsewhere. Groundwater was lowered and fields on the lower and middle reaches of streams would have been destroyed first. The effects of arroyo cutting were, according to Dean, postponed by moving upstream in Tsegi Canyon.

Karlstrom et al. (1976:161) concluded their study by stating, "Thus, the hydrologic curve seems to bear out our thesis that cultural adaptations, as delineated by our phases, were largely produced by environmental alterations." Several criticisms have been leveled at their conclusions and particularly at the statement quoted above. There is general disagreement with the assumption that, because environmental and cultural changes are closely correlated, the latter were brought about by the former. Additional evidence is needed to document whether, in fact, subsistence strategy shifts did occur as a response to environmental changes. The argument about abandonment having been caused by a drying of the climate, which made dry farming impossible, is weak because it fails to consider alternatives pursued earlier in the sequence, such as floodwater farming and a reversion to hunting and gathering.

In addition to the general criticisms above, more specific arguments made in the paper have been questioned by ongoing research. First, the recently excavated Lolomai sites indicate that farming was practiced in the uplands at a time when a major drought was postulated in nearby Kayenta and Durango regions. Second, Dinnebito phase sites were located in the uplands as well as the lowlands, during what has been termed a drought interval. Third, and finally, during the late Toreva phase a reversion to a more diversified agricultural-hunting-gathering strategy was noted <u>prior</u> to the onset of drought conditions and followed by the abandonment (S. Plog 1978a). Thus, although climate may have played a major part in the strategy-changing decisions made by the populations, clearly it was not the key factor in effecting these changes.

Synthetic Organizational Models

Martin and Plog (1973) were among the first to employ organization as a variable that contributed to the abandonment of many areas in the northern Southwest. They suggested that increases in population that began A.D. 900-1000 stimulated budding into areas more marginal for agriculture. The increased population and resultant increased population density in more marginal areas would have severely curtailed seasonal mobility. Areas that once may have been exploited in times of crop failure now would have been inhabited by others. Individual groups thus became more territorially restricted. Certain developments would have been necessary to have allowed populations to remain in these marginal areas, such as water-control systems and economic links between parent and daughter communities. Stress, more likely to have been felt by people in marginal areas, rapidly would have been transmitted to people upon whom they were dependent, in less marginal areas. This stress may have been amplified by further population increase and/or human degradation of the environment, which was discussed earlier. Ultimately, the only areas of the Southwest that remained occupied were those where subsistence strategies were well suited to the environment, or superior organizational systems kept populations in more marginal areas viable.

This model, particularly with the adoption of expanded social networks, appears to apply to the Black Mesa data and also may apply more widely throughout the region. The increase in population has been documented (Swedlund and Sessions 1976; Layhe 1977b). Prior to about A.D. 900, the more permanent settlements appear to have been concentrated along major washes. Upland resources also were exploited at this time, but most sites in that zone were small and may have been occupied only seasonally. Although there is evidence of cultivated plants at these upland sites, wild plant resources were used heavily.

With the increased population, upland areas became occupied more permanently. Cultivated plants became a major portion of the subsistence base, although the only upland areas suitable for floodwater farming are catchment basins much smaller than those of the major washes. Thus, upland floodwater and dry farming would have suffered more easily from erratic rainfall. The entire system would have been more susceptible to environmental variability because (1) lowland populations no longer could have relied upon upland resources in times of need, (2) upland farming provided a less stable resource base, and (3) stress felt by upland populations would have been felt rapidly by their lowland contacts.

There is evidence on Black Mesa that redistributive networks may have been functioning to alleviate some of the difficulties in utilizing these more marginal areas. Phillips (1972) developed a model that recognizes two site types in existence during the Toreva phase. Primary sites have been defined as

> having those facilities required by the Anasazi for complete internal maintenance of their cultural system, including facilities for habitation, storage and preparation of food, and socioreligious activities. . . . An idealized plan of a primary site includes a masonry room block with connecting jacal rooms, a kiva, and a trash area in line with one another; between and to one side of the masonry block and the kiva, a mealing pithouse is found (Phillips 1972:200).
>
> Secondary sites are defined as capable of satisfying the immediate biological needs of the inhabitants, but lacking at least the important dimension of socioreligious facilities i.e., a kiva. For this the inhabitants must have relied on primary sites. Kivas, then can be hypothesized as serving an integrative function between the two site types (Phillips 1972:201).

Primary and secondary sites are found in clusters in both the upland and lowland areas of the mesa, although a single aggregate rarely overlaps the two areas. Analysis indicates a strong tendency for secondary sites to be located in the upland aggregates (89%) and a somewhat less pronounced tendency for primary sites to be located in the uplands (66%). Upland sites, regardless of type, most often are located either on cultivable land (sage plains) or near it (in the transition zone). Secondary sites show a slightly greater tendency than primary sites (22% versus 13%) to be located in pinyon-juniper zones. There are too few lowland secondary sites to make this comparison, but primary lowland sites most often are located in the transition zone (67%). The analysis indicates that secondary sites show a tendency to be located in areas more marginal for farming.

More recent analysis by Powell (1980), on 41 sites dating from the Dinnebito through Toreva phases, provides an interesting comparison to Phillips' analysis. Instead of making the primary/secondary site distinction, Powell split the sites into those with less than 12 m^2 versus those with greater than 17 m^2 of interior habitation space (jacals, ramadas, and pithouses). A gap in the size distribution was used as a natural breaking point between these two figures. The sites with the smaller habitation areas (in conjunction with other variables) were considered summer-occupied sites where most activities occurred outside. The opposite was assumed for the sites with the greater interior habitation areas.

Powell found that 76.9% of sites in the former group were located in the uplands, whereas 57.7% of the latter group was located there. If equivalents must be identified between the categories in Phillips' and Powell's analyses, even though originally they were defined by different criteria, the less architecturally complex sites, Phillips' secondary sites (89% of which were in the uplands) would correspond to Powell's summer-occupied sites (76.9% of which were in the uplands). Phillips' primary sites (66% in the uplands) then would correspond to Powell's winter-occupied sites (which were in the uplands 57.7% of the time).

Taking into consideration the fact that the samples used in these analyses were chosen differently, and that the categories were defined with different goals in mind, the results indicate similar trends, i.e., sites with greater investment of labor in their construction are located in lowland areas more often than sites with less of a labor investment. Difficulties arise in interpretations, however, because Powell found the vast majority of supposedly summer-occupied sites in the uplands, precisely the area that Phillips identified as more marginal for farming. The discrepancy might be explained by suggesting that farming never became very important in the subsistence system; thus the marginality of the upland farming areas is not critical. It could be explained also by pointing out that the upland/lowland distinction has received more attention than it warrants on Black Mesa. The distance between the two areas is such that fields in one area easily could have been tended by people living in the other. The shift to upland farming could have been in response to arroyo cutting that entrenched the lowland washes beyond the point of utility for farming; however, the climatic reconstructions do not support an arroyo-cutting episode at this point. These propositions remain to be tested.

Phillips believed that the pattern of formal integration did not extend beyond the site clusters because of the regular association of kivas within each site cluster. He suggested that exogamous marriage ties linked the clusters, which resulted in the "cultural coherency" evident on Black Mesa.

Other researchers in the region also felt that there was little connectivity between sites:

> Furthermore, each site was probably relatively independent from a social, religious, and economic standpoint (Neely and Olson 1977:71, for Monument Valley).

> Villages of this period were essentially self-sufficient and localized (Lindsay et al. 1968:364, about the period A.D. 1100-1200 at Navajo Mountain).

The alternative view has been expressed by Anderson (1969:63) in discussing the period A.D. 1000-1200 for Tsegi Canyon:

> Quite likely then, the whole canyon and its environs comprised a far-flung community, and social and ceremonial ties were less localized and settlement more flexible than in the 1200's when fewer and larger villages formed.

Evidence from the Glen Canyon region in the form of trails pecked into the canyon walls demonstrates links between sites and between sites and resource areas:

> The trails argue that there was habitual travel from one center to another, to say nothing of wide-ranging hunting and collecting trips, and we can postulate a vast network of now forgotten trails (some routes were metamorphosed into modern stock or primitive roads) over the whole of Kayenta land and the rest of the Pueblo domain. The ease and frequency of inter-village contact observed ethnographically has apparently never been fully appreciated or sufficiently stressed as being equally true in prehistoric times, but the highlighting of the Glen Canyon region trail system puts emphasis on an important ecological and sociological point—the canyon dwellers were not confined to the canyons (Jennings 1966:45).

Evidence for a wider network of ties also exists on Black Mesa in the form of Standing Fall House, the 55 room cliff dwelling on the north rim. Several lines of evidence including room function, the great abundance of corn, and the long use span, but few artifactual remains, have been used to infer that this site functioned as a storage and integrative center for a large nonlocalized population (Klesert 1979b). Religious functions at the site were served through the use of two kivas.

Tree-ring cutting dates for Standing Fall House range from A.D. 971 to 1058 (Dinnebito to early Lamoki phase), which indicates that this larger integrative network would have been operative even earlier than the smaller scale networks postulated for the Toreva phase. In fact, limited survey in the rim area suggests a population peak during the Dinnebito phase (A.D. 875-975) and abandonment of the area by the Lamoki phase (A.D. 1050-1075). This decline in population in the north, early on, may have contributed to the population expansion beginning A.D. 950, to the south, in the eastern and western lease areas (Swedlund and

Sessions 1976; Layhe 1977b). If this had been the case, the increase in population, when considering all of northern Black Mesa, may not have been as considerable as once was believed. However, unless another site like Standing Fall House is found, and Klesert's interpretation is correct, a major change in organization took place from the larger single integrative network to a larger number of smaller networks. Similar integrative sites, such as Promontory Ruin in the Chinle Valley (Morss 1927; Lofton 1974), NA 8604 on the Shonto Plateau (Anderson 1969), and NA 8171 in the Cow Springs area (Ambler and Olson 1977), were discussed in the Culture History chapter.

Phillips' results have been criticized at another level as well. S. Plog (1977a) noted that some Toreva phase sites do not fit into either the primary or secondary site category. His analysis has shown that masonry rooms are the best predictors of other site features. Standardized site plans generally are found when presence of masonry rooms is the criterion used in selecting sites for excavation. Excavation of sites with a wide variety of surface features indicates there was much more variation in site plan than had been recognized previously.

In partial support of Phillips' hypothesis about sites with kivas serving an integrative function, Plog found that kivas on sites with masonry (storage) rooms are larger than on sites without them and may have served a larger population than that residing at the site. Thus, although some of the details of Phillips' model may be incorrect, the basic hypothesis of intercommunity integration still appears quite reasonable.

Recent research by S. Powell (1980) has questioned many assumptions presently held about subsistence and settlement as it changed over time on Black Mesa. Briefly, she found that an average 60% of sites were located in upland areas and 40% in the lowlands. Most divergent from the mean figure are sites occupied after A.D. 1050 with interior roofed areas less than 12 m^2; 87.5% of them are in the uplands. However, floral remains do not support the argument made for a shift to dry farming in the uplands made by Karlstrom et al. (1976). No trend was apparent toward increased reliance on cultigens; instead, the diversity of floral remains increased over time.

Powell used the increase in floral diversity in support of her model of a change from primarily summer use of the mesa prior to A.D. 1050 to year-around use after that date. Variables studied that suggested this pattern are interior site space, artifact density, hearth location, and faunal remains. Although they stated that the available data do not support it, Neely and Olson (1977) have suggested predominantly summer use of Monument Valley as well. More research needs to be done along these lines to determine whether the evidence, for example, in Long House Valley and/or Klethla Valley provides the complementary seasonal occupation for the early sites.

Nelson (1978) used many of the above ideas, with some refinements, to explain the abandonment of northern Black Mesa. He focused on a series of causal processes rather than, for example, population pressure or environment alone. He viewed the period prior to the abandonment as the critical period during which attempts were made to cope with the rapid population growth. He disagreed with the belief that the shift to use of the uplands signifies a shift to dry farming. He used data from the eastern lease survey to demonstrate that during this period population shifted toward streams, but they were streams of lower drainage rank than previously. Nelson viewed this as a shift to smaller floodwater fields rather than to dry farming.

He agreed that increased use of marginal lands would have placed stress on the entire system by increasing the frequency of crop failure even in times of stable environment. A redistributive system would have been to the advantage of all by providing for groups whose production was insufficient in a given year.

This redistributive system, Nelson suggested, would have resulted in an increase in the level of mutual responsiveness among segments of the system or an increase in the coherence of the system. Nelson measured this coherence by calculating the percentage of the population residing in secondary sites (from Phillips' classification) presumably in more marginal areas. He found a high degree of correlation between total site area and percentage of site area in secondary sites. He demonstrated an increase in integration during this period by documenting a decrease in the ratio of kivas to relative population estimates, indicating that greater numbers of people acted in concert.

Data on the abandonment of Black Mesa suggest an orderly but rapid exodus. Gumerman and Euler (1976) noted the absence of ground stone on Toreva phase sites and suggested that the move was planned, and the population curves derived suggest a fairly rapid process. Nelson suggested that these patterns imply integrated action on the parts of large numbers of people and not household-by-household movement. He argued that a depopulation or abandonment of the area caused by environmental degradation would have been much slower and would have stopped when the number of people remaining could have been supported under the changed conditions. (Dean [1969] would disagree with this; he felt that the exodus was self-perpetuating in that, after a certain point, people would have left merely to join their relatives.)

Nelson argued instead in support of a situation of hypercoherence, which results from overresponsiveness among system components. He suggested that such a situation may have occurred because of the large percentage of the population depending upon high-risk, low-yield agricultural plots and, as a result, on each other. If a few bad years had been experienced by a part of the population, this would have put a strain on the rest.

S. Plog (1978b) studied patterns of population increase in an effort to understand population stability. Three models of population growth were examined: (1) changes in population (ΔN) become constantly smaller as population smoothly moves toward equilibrium; (2) absolute value of ΔN is increasingly smaller as population overcorrects for successive positive and negative values of ΔN; and (3) ΔN is increasingly greater rather than smaller, alternately in positive and negative directions, a positive feedback system. The first two models are deviation-counteracting and lead to an equilibrium situation. The third model, however, is a deviation-amplifying system in which the population is heading toward extinction resulting from too low a negative value from which recovery is impossible. Statistical tests indicate a strong correlation between the Black Mesa situation and the deviation-amplifying model, which indicates that population never reached an equilibrium on Black Mesa.

Nelson did not discuss the reversion to the earlier focus on hunting and gathering now recognized at later Toreva phase sites. However, this attempt to cope by the population may have failed as a result of human-induced degradation of the environment, not only in the lowland areas but in the uplands as well. This factor, coupled with population pressure that limited the territory of exploitation available to each group, may have made remaining on Black Mesa almost impossible.

S. Plog (1980a:10) concluded by stating:

> In the end, abandonment was a result of the long-term inability of most Southwestern populations to develop adequate organizational frameworks and procurement systems to regulate both population and resources in a marginal environment.

Raw Material Exchange in the Context of Culture Change

The following summary model is based upon the latest interpretations of the data for which there is solid evidence. Areas that still are considered of questionable interpretation will be pointed out as such.

Generally it is agreed that population increase in the Southwest began about A.D. 700-850 and lasted, for Black Mesa, until about A.D. 1100 or slightly earlier (Swedlund and Sessions 1976; Layhe 1977b). However, the increase in population for Black Mesa was not continual; it proceeded in stages, with ever-increasing rates of growth. S. Plog (1978b) has found that this pattern fits a deviation-amplification model in which a population equilibrium never is reached. Consequences for the population entail imbalances between numbers of people and resource productivity.

On Black Mesa, the earliest permanent habitations were in the lowland areas, with the uplands used on a seasonal basis. (Powell [1980] suggested that the earliest occupation of the entire study area on Black Mesa may have been on a seasonal basis, but additional research must be done to substantiate this hypothesis.) With the increase in population came increasing use and habitation of the upland zone, even though the available farmland there is limited to small catchment areas. With the settlement of areas unoccupied previously and the increase in population, mobility of populations had to have been curtailed. These actions should have increased the population-resource imbalance because farming in upland areas should have been riskier than along the major lowland washes. Even if the questioning of increasing reliance upon agriculture is substantiated (S. Plog 1978a; Powell 1980), the decrease in mobility should have rendered a hunted and gathered diet more difficult to procure. It has been suggested (Braun and Plog 1980) that the apparent switch from larger to smaller game may be a reflection of the decrease in mobility. Agricultural pursuits have a tendency to degrade the natural environment, which would compound the problems (Catlin 1978), as would adverse climatic conditions (Karlstrom et al. 1976).

Lightfoot (1979:320-321) outlined five strategies used to minimize the risk of resource uncertainty. The strategies and evidence for them on Black Mesa will be presented below.

1. Resource diversification is represented most clearly on Black Mesa in the diversity of plant foods found at sites (Moore 1978; Ford et al. 1977; Cowan et al. 1978). The Hopi strategy of varying the location of agricultural fields is another means of diversifying the resource base (Hack 1942), but no prehistoric evidence for this has been found on Black Mesa. Strategy #1 would have become increasingly difficult to pursue as population increased and areas previously exploited in times of scarcity began to be controlled by others.

2. Migration to more hospitable areas was probably going on at the local level throughout the sequence and may be the reason for the paucity of sites on the mesa from A.D. 1-800 (Ware 1976). The abandonment of northern Black Mesa by about A.D. 1150 also may be understood in light of this strategy (Karlstrom et al. 1976).

3. Warfare. No evidence of raiding to procure foodstuffs or for any other reason has been found on Black Mesa.

4. Technological innovations. Water control devices, the most common example of labor intensification, are rare to nonexistent on Black Mesa. However, evidence does exist for the refinement of storage facilities and for increases in storage capacity over time (see Chapter II).

5. Food exchange. The preceding list should have served to illustrate the pursuit of a number of these strategies on Black Mesa. They are not mutually exclusive and it is likely that several were practiced simultaneously. The focus of this study, however, will be on the fifth strategy of resource risk reduction, that is, exchange. Although Lightfoot (1979) presents it as "food exchange," it is assumed

here that the same ties that facilitated food sharing operated also in the exchange of chipped stone raw materials (S. Plog [1977b] and Tuggle [1970] made similar assumptions for ceramic exchange). Many ethnographers have found that exchange networks that are crucial only at certain times (e.g., scarcity or mate exchange) are kept viable through the exchange of other items (Rappaport 1968). For example, as Warner (1937:458) states:

> The native sometimes exchanges things he possesses for things he needs and can't get from his territory; but the larger basis of trade in north-eastern Arnhem Land is one of social reciprocity which establishes a social bond between the traders and enlarges the social periphery of each.

The exchange of chipped stone raw materials could have served in such a capacity.

Several factors suggest that the exchange of chipped stone raw materials actually may have had more to do with maintaining social ties rather than with strict economic requirements. First, chippable stone materials are available in great quantities on Black Mesa (see Chapter IV). Second, these locally available materials comprise a large proportion of the lithic assemblages (Green 1977). Third, materials available on the mesa fulfilled the same range of functions as materials that were imported and were used almost exclusively during the earliest time periods (Anderson 1977). Finally, material available in outcrop only on Black Mesa (baked siltstone) was identified by the author at Long House Valley sites and may have been at Basketmaker sites in Marsh Pass (Guernsey and Kidder 1921). This could indicate either that Black Mesa populations were utilizing resources in Long House Valley and brought material down from the mesa, or exchange in locally available chipped stone raw materials took place. The former possibility, that some sites in Long House Valley might be evidence of Black Mesa populations utilizing this area also, is beyond the scope of this paper (see Powell 1980 for arguments of seasonal use of Black Mesa sites). With cherts available in close proximity to Long House Valley sites (Czaplicki 1977; see also Chapter IV) economic need for Black Mesa chipped stone raw materials is difficult to substantiate.

In the following paragraphs arguments will be reviewed concerning the impetus for increasing the intensity of interaction among sites on Black Mesa. Changes in interaction will be traced as they are reflected in the chipped stone raw material assemblages. Several specific forms these changes in interaction could have taken will be proposed for testing.

Economic situations in neighboring settlements in the Southwest may vary considerably from year to year because environmental conditions are quite localized (Ford 1972a). Neighboring fields may receive disproportionate shares of the elements in different years and important wild plant foods such as pinyon nuts and juniper berries are available in large quantities only occasionally in a given locale (Lightfoot 1979). Thus, fairly regular cooperation among settlements probably was necessary for survival in this unpredictable environment.

This cooperation could have been structured in several ways, depending upon whether exchange partners were institutionalized and whether exchange was unidirectional. For example, there might have been a relatively balanced exchange based on whose crops or gathering territories were favored in a given year. Population may have been low enough within the survey area to have allowed everyone to participate in the same resource risk reduction network. Alternately, several settlements may have shared more regular trading relations among themselves than with others. Exchanges between settlement groups may have occurred if needs could not have been satisfied within the established trading circle. These institutionalized relationships might have existed among settlements in areas of equal economic potential or may have functioned between parent communities in more favored locations and daughter communities in more marginal locales (Phillips 1972; Martin and Plog 1973). In the latter case the exchange is expected to have been asymmetrical (F. Plog 1977). Although the flow of goods would have been mainly unidirectional, it would have benefited all by keeping population down in the donor community (Martin and Plog 1973). (The sites for this analysis are solely from northern Black Mesa, but it is recognized that sites outside the arbitrarily defined study area probably participated in these exchanges as well.) The other impetus for interaction to be discussed is in the social rather than the economic realm.

Through simulation analysis Wobst (1974) has suggested a figure of 475 interacting persons as necessary for each person who comes of age to find a suitable mate. Interaction with a larger number of people than that required for economic needs alone might have been necessary for a self-sustaining marriage network among groups (like those on Black Mesa) with low population densities. Ties among people in the marriage network may have been maintained loosely through the periodic exchange of chipped stone raw materials and other goods. If population density increased, the extent of the marriage network should have decreased.

Thus, if raw materials with distant sources were obtained when the marriage network covered the greatest geographic area and then the marriage network contracted, the area from which these materials had been obtained no longer would be included in the marriage network and they should not appear in the assemblages. Recent analyses of both ceramics and chipped stone raw materials provide support for this model.

Hardy et al. (1980) examined the distributions over time of Black-on-red ceramics, specifically San Juan Redware and Tsegi Orange Ware. San Juan Redware was obtained from southeastern Utah and southwestern Colorado (about 80 to 120 km away) where it figured prominently in assemblages dating between the eighth and tenth centuries A.D. Tsegi Orange Ware also was imported but its origin was significantly closer than that of San Juan Redware, although it has not yet been determined (Shirley Powell, personal communication). Black-on-red ceramics were present on northern Black Mesa sites from A.D. 800 to abandonment, about A.D. 1125-1150. San Juan Redware was more abundant early in the sequence, until about A.D. 900 when frequencies of Tsegi Orange Ware, the import with the closer source, began to increase. Thus, the distance from which at least certain ceramics were obtained decreased over time and may be a reflection of the contraction in the marriage network.

Fernstrom (1980) had similar results in her analysis of chipped stone raw materials from 12 excavated sites. As population density increased, the geographic extent of the procurement area for chipped stone raw materials decreased. This general phenomenon is common even among twentieth century populations (Haggett 1971).

> Specifically it is suggested that the geographical limits of Anasazi exchange spheres and the sizes of twentieth-century territories may be governed by the number of informational nodes with which a given household (for example, point 'A') can and must maintain contact. Least effort models (Zipf 1949) suggest that as population density around 'A' increases, this number of informational nodes will be filled by those households occurring closer and closer to 'A'. Households further from 'A', with which 'A' was originally interacting, will fall out of 'A's' interaction sphere. As each household's interaction sphere within an area contracts, the interaction sphere for the area as a whole should be observed to contract in toward centers of the population 'gravity' (Fernstrom 1980:194).

Changes in interaction patterns among sites on Black Mesa should be monitored with the knowledge that the external exchange spheres were contracting.

Interaction patterns on the local level may mimic those on the larger scale by contracting with increased population density. More restricted territories might have been defined as population increased. Alternately, there may have been few enough people on Black Mesa during any particular time for them to have continued to interact on a regular basis. The contraction in the interaction sphere that diminished the amount of raw material from distant sources may have been merely an external process that had little to do with local site relations.

It is most likely, however, that although the increase in population density might have resulted in contraction of the marriage network, the same increase in population would have rendered the resource base more unreliable, thus necessitating increased interaction on the local level. There is support for this position in Fernstrom's analysis (1980). She found that although the maximum distance from which raw materials were obtained decreased, the overall amount of imported materials increased. Thus, imports available closer to the mesa became more important over time than imports from all distances combined had been earlier.

Although the marriage network may not have been used regularly as a vehicle for redistributing foodstuffs in times of scarcity, it may have done so when the need became critical. The situation described by Schelberg for Chaco Canyon may have obtained for Black Mesa also.

> The implication is that if there is a drought on the north side of Chaco Canyon there will probably be one on the south side as well; therefore, a solar based agricultural system (cf. Odum and Odum 1976) which was probably initially labor extensive would do better to spread itself throughout its region rather than to concentrate itself in one small area. By doing this the effects of the spatial variation in rainfall can be mitigated and redistribution throughout the region becomes important. . . (Schelberg 1980:421).

As population density increases the size of the area required within which to find a suitable mate decreases. However, the decrease in geographic extent would leave the interacting group of people with a smaller zone for resource procurement and less environmental diversity. Thus, a precarious situation could arise easily in times of environmental adversity.

This line of reasoning is in accord with the situation of hypocoherence hypothesized for the mesa (Nelson 1978; S. Plog 1978b), which holds that the intensity of interaction became so great that stress felt by people in one area soon was felt by all. With fewer ties off the mesa due to the contraction of the marriage network, the people may have had to intensify production (i.e., through the use of water control devices, for which there is no evidence on Black Mesa) or become more mobile to obtain a more secure food supply. This situation would have been compounded by the increase in arroyo cutting that occurred at the same time (Karlstrom et al. 1976).

Before proceeding to test the above models it will be useful to summarize the alternatives in the context of the chipped stone raw material data. If interaction on Black Mesa increased prehistorically, site relations as evidenced by chipped stone raw materials should take one of the following forms:

1. The nonlocal component of chipped stone raw material assemblages should become increasingly similar over time at all sites in the study area. If differences in raw material use did exist, it is expected that the differences will be most obvious among the nonlocal raw materials because the ones with local sources should have been available to all those who lived on the mesa. The size of the survey area may be too small for distance to significantly have affected interaction intensities among sites (Green 1978). It is not assumed that the survey area coincides with a cultural unit; it may be small enough to have contained only part of a larger system or it may have parts of several systems. Integrative sites (perhaps represented by Standing Fall House; see Chapter II) with numerous storage and ceremonial rooms and little evidence of habitation, are one form the cooperative element of such an all-encompassing system could take.

2. The nonlocal component of chipped stone raw material assemblages should become increasingly similar over time at groups of sites, and different materials may predominate among different site groups. This alternative assumes that information about sources and/or exchange

partners was not shared among all sites on the mesa. As mentioned earlier, the sharing of raw materials might have been among sites with similar resource procurement potential or might have been between parent and daughter communities. In the latter case, one of the sites might exhibit the qualities of a redistributive center for chipped stone raw material(s), such as significantly greater use of an imported material, caches of imported materials, and perhaps more evidence of the primary stages of manufacture for that material.

3. Groups of sites with similar nonlocal raw material assemblages should be identifiable, but over time assemblages from different site groups should become more similar to one another. This alternative provides for a hierarchy of interaction, but does not assume that the closer the proximity the more intense the interaction. This assumption has been questioned with regard to ceramic design styles (S. Plog 1977b) and, although the argument was made earlier that chipped stone raw materials are a more direct referent for interaction (see Chapter I), there is no need to assume that sites located closest to one another had the deepest involvement with one another. In fact, in the case of the parent-daughter community relationships, they are expected to be located at some distance from one another in slightly different environmental zones to have necessitated the asymmetrical exchange pattern discussed above.

The second level of the hierarchy of interaction, that of increasing interaction among sites in different groups, should have become important once needs could no longer have been satisfied at the level of the site group. This situation should have arisen as population density increased, the spatial extent of the marriage network decreased, and interaction at the local level became more intense to cope with the increased resource risks created by the higher population density and the decrease in geographical area over which contacts once spread.

The null hypothesis for this analysis is that interaction among sites on Black Mesa did not increase over time. Two alternatives for the null hypothesis exist: (a) interaction levels, as measured by shared chipped stone raw materials, remained the same over time; or (b) interaction levels decreased over time. These alternatives are unlikely but could have occurred if dependence on agriculture did increase and this increased dependence on agriculture resulted in increased village autonomy. The alternatives presented above for both H_1 and the null hypothesis are mutually exclusive for any one time but may have existed serially.

In the preceding pages, evidence has been presented supporting the existence, for Black Mesa at least, of strain in the adaptation to the environment (Cohen 1977). This evidence was in the form of (1) spread of settlement into previously uninhabited or seasonally utilized upland zones, (2) use of the small catchment areas available in the uplands for farming, (3) a decrease in the numbers of large game in favor of smaller game animals, and (4) sagebrush invading grassland zones, thus degrading the environment.

These increases in environmental uncertainty were caused and compounded partially by an increase in population and a concomitant decrease in mobility. Thus, evidence of an increase in interaction is expected among Black Mesa sites as a response to these environmental uncertainties (Braun and Plog 1980).

CHAPTER IV

THE DATA BASE

Modern Climate

Black Mesa lies in the northeast corner of Arizona on the Navajo and Hopi reservations. Apparently there is some disagreement as to whether Black Mesa was named for its dark appearance, attributable to its dense cover of pinyon and juniper that provides a stark contrast with surrounding areas, or as a result of the all-important coal with which it is richly endowed. Gregory (1916:190) presented the name as a translation from the Navajo Dzilijini, which means black streak mountain, presumably in reference to the coal beds.

The mesa is approximately 120 km east-west and 80 km north-south. It is basin-shaped; the maximum altitude of 2,440 m occurs at the northern rim, with altitudes at the interior ranging from 1,980 m to 2,130 m. The steep escarpment on the north side is not evident to the west and to the south, where the mesa gradually slopes down to the Hopi Mesas, the southernmost extensions of Black Mesa.

Topography on the mesa consists of rolling hills dissected by small washes. There are no permanent streams on Black Mesa, although water can be obtained, usually the year around, from the major washes, either in standing pools or from pits dug into the wash bottom. The single known permanent spring on northern Black Mesa is located in the northern reaches of Coal Mine Wash, associated with the largest site known on the northern mesa, a 55 room cliff dwellng of transitional PI-PII or early PII date (Standing Fall House). Other springs are located around the edges of the mesa at the contacts between certain geologic strata and, to the south, in the Hopi area (Gregory 1916). The principal washes (West Fork of Coal Mine Wash, Coal Mine Wash, and Lower and Upper Moenkopi Wash) begin near the northeast escarpment and cross the mesa from northeast to southwest (Gumerman et al. 1972; Klesert 1978) (see Figure 2). Streams that drain Black Mesa on the southwest flow southward into the Little Colorado River. Those on the north and northeast flow northward to the San Juan River. The only perennial stream in the latter area is Laguna Creek, which flows through Tsegi Canyon, to the northwest of the mesa (Beaumont and Dixon 1965).

Black Mesa lies within the upper Sonoran life zone (Lowe 1964). Unfortunately, there are no weather records available for northern Black Mesa. Betatakin, at Navajo National Monument, the most comparable area that has complete weather records, evidences mean minimum and mean maximum winter temperatures of 20 and 41 degrees Fahrenheit, respectively. Mean minimum and mean maximum summer tempeatures there are 49 and 84 degrees Fahrenheit, respectively. Summer maximum temperatures at the field camp on Black Mesa have been recorded as high as 96 degrees Fahrenheit (Gumerman et al. 1972).

Precipitation and length of the growing season or length of time free from killing frosts, critical agricultural factors, vary considerably in northeastern Arizona (see Table 3). According to Hack (1942), the ideal is 30 cm of rainfall and a 130 day growing season. As can be

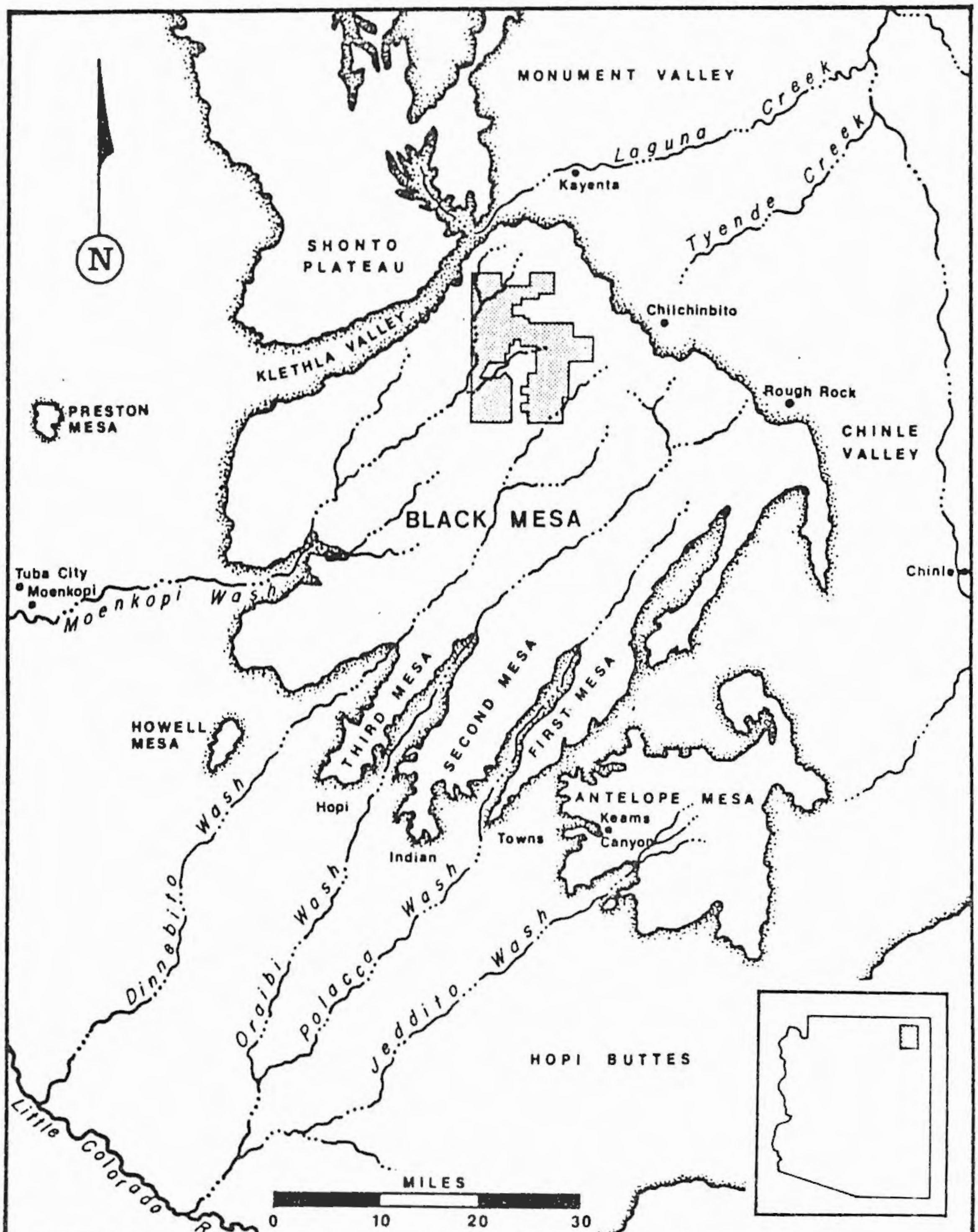


Figure 2. Black Mesa and vicinity.

Table 3. Length of Growing Season, Mean Annual Rainfall, and Elevation at Various Northeastern Arizona Localities

Location	Growing Season (days)	Mean Rain- fall (cm)	Ele- va- tion (m)	Ref- er- ence
Black Mesa (incl. Hopi Mesas)	120-150	25-33	1,980-2,330[c]	e
Canyon de Chelly	146		1,800-2,100	h
Chinle	124		1,580	d
Flagstaff	114	46[e]	2,100	h
Kayenta	136	20[e]	1,770	h
Keams Canyon	105		2,010	d
Long House Valley	155	28	1,950	c
Monument Valley	155	18-25	1,540	g
Navajo Mountain, (A)	225	8-13	1,340	f
(B)	170	46	2,130	f
Shonto Plateau		25-28	2,240[c]	a
Tsegi Canyon	155	28	2,230	b
Tuba City	133	15[e]	1,370	d

[a]Anderson (1969).

[b]Dean (1969).

[c]Dean et al. (1978).

[d]Gregory (1916).

[e]Hack (1942).

[f]Lindsay et al. (1968).

[g]Neely and Olson (1977).

[h]Sellers and Hill (1974).

seen from Table 3, this ideal often is not achieved. In fact, according to Gregory (1916:67), "When, however, a period of several years is considered, it appears that the normal length of the growing season may be much shortened." For example, the growing season in Tuba City may be shortened by as much as two weeks in a given year. It is unfortunate, but true, that crops and in turn humans, have to deal with these figures on a yearly basis and not with the mean figure. Thus, mean growing seasons that are borderline often will prove insufficient to produce a mature crop.

Summer thundershowers have been the dominant form of precipitation since about A.D. 1700 (Karlstrom et al. 1976) and occur from mid-July through September. Washes that normally are dry often flood during this period but return to their usual dry state quickly thereafter. The first winter snows begin in late October or early November and may continue into April, although it is seldom more than a few centimeters at any time (Gumerman et al. 1972). Although the actual mean for Black Mesa is unknown, annual precipitation at altitudes between 1,830 and 2,290 m on the reservation varies from 25 to 41 cm (Hack 1942). However, variation in precipitation from year to year ranges between half and twice the mean figure. "For a region whose maximum precipitation is insufficient for agriculture and in places for grazing without irrigation these great variations from year to year are matters of concern" (Gregory 1916:60). The weather patterns also are extremely localized. The following example serves to illustrate the point. "Over the entire plateau province 1905 and 1911 were seasons of excessive rainfall, causing in the latter year destructive floods in all the larger valleys. It is interesting to note, however, that during the flood year of 1911 the rainfall at Tuba was about normal" (Gregory 1916:60). Thus, even in bad years the potential for obtaining food elsewhere, either directly or through gifts and/or exchange with others, should still exist. Ford's (1972a) research on the Eastern Pueblos supported these early findings.

The dominant factor limiting the distribution of wild plant species on Black Mesa is elevation. Increases in precipitation and decreases in mean temperature and growing season are correlated with it. Slope, exposure, soil texture, moisture-holding potential, nutrient content, and soil depth are all mediating factors (Miksicek 1976). There are four primary plant associations within the study area: (1) pinyon (Pinus edulis)-juniper (Juniperus osteosperma) with sagebrush (Artemisia tridentata) understory; (2) pinyon-juniper with cliffrose (Cowania mexicana) understory; (3) sagebrush; and (4) sagebrush with dwarf pinyon intruding. Elevation ranges for the associations differ and are presented in Table 4.

Topographic situations and soils also differ among the associations. Pinyon-juniper associations occur primarily on ridge slopes with shallow soils and often with outcrops of sandstone. Sagebrush associations are found most often in valley bottoms with loamy soils from 60 to 90 cm deep. The latter areas are believed to be where prehistoric agriculture took place due to the soil's depth, fine texture, and nonalkaline quality (Klesert 1978). Sagebrush and grassland areas are interspersed with pinyon-juniper in the north, but in the south they become quite expansive, particularly around the juncture of Upper

Table 4. Elevation Ranges for Primary Plant Associations

Association	Elevation Range
sagebrush	1,950-2,100 m
pinyon-juniper-sage	2,010-2,130 m
sagebrush-dwarf pinyon	2,040-2,130 m
pinyon-juniper-cliffrose	2,070-2,130 m

and Lower Moenkopi washes. Common grasses include Blue stem (Agropyron smithii), sand dropseed (Sporobolus cryptandrus), Indian ricegrass (Oryzopsis hymenoides), and blue grama (Bouteloua gracilis). Snakeweed (Gutterezia sarathrae), rabbitbrush (Chrysothamnus sp.), and saltbush (Atriplex canescens) are quite common, and wolfberry (Lycium pallidum), although not so common, often is a good indicator of prehistoric sites because it grows in disturbed or highly organic soil. In isolated side canyons in the far northeastern part of Black Mesa, and out of the study area proper, are Douglas fir (Pseudotsuga menziesi), aspen (Populus tremuloides), ponderosa pine (Pinus ponderosa), and Gambel oak (Quercus gambelii) (Gumerman et al. 1972; Lowe 1964).

Vegetation on Black Mesa has undergone considerable change since the advent of pastoralism in the mid to late 1800s. Grazing pressure has changed the relative abundance of various species to the advantage of certain poisonous shrubs such as snakeweed, and to the detriment of the edible grasses, Indian ricegrass, blue grama grass, and galleta grass (Hilaria jamesii). With the possible exception of the hackberry (Celtis reticulata), which has been identified in flotation samples but not in modern communities, it is believed that grazing has affected the relative abundance of species but has not effected changes in the types of species present (Miksicek 1976). (See also discussion of Catlin 1978 and Moore 1978 in Culture Change Models chapter.) Two plant species were introduced to the mesa in historic times: Russian thistle (Salsola kali), which is now ubiquitous, and salt cedar or tamarisk (Tamarix pentandra), which grows along washes in some areas.

Wild animal life in the area today is not abundant and includes jackrabbits (Lepus sp.), cottontails (Sylvilagus sp.), mule deer (Odocoileus hemionus), and various rodents, lizards, rattlesnakes, and small birds (Gumerman et al. 1972; Douglas 1972).

Prehistoric Climate

Karlstrom et al. (1976) conducted a study of the paleoenvironment of Black Mesa employing data on geologic late Quaternary alluvial and colluvial deposits, archaeology, dendroclimatology, and palynology. Climatic changes were inferred from hydrologic changes, i.e., they equated aggradational intervals with "increased hydrologic competence, higher water table levels, and thus presumably more mesic climates" (Karlstrom et al. 1976:157). Erosional intervals were found to have been centered at A.D. 1710, A.D. 1472, A.D. 890, and A.D. 350 and were followed immediately by aggradational intervals. Karlstrom, Gumerman, and Euler state that, if Schoenwetter (who now disavows this position) is correct about a summer-dominant rainfall regime being related to high effective moisture accompanied by erosion, and winter-dominant precipitation being related to high effective moisture accompanied by alluviation, then summer-dominant regimes occurred A.D. 50-350, A.D. 600-875, A.D. 1150-1450, and A.D. 1700-present, and winter-dominant regimes occurred 250 B.C.-A.D. 50, A.D. 350-600, A.D. 875-1150, and A.D. 1450-1700. (Corresponding phase dates can be seen in Table 2.) Within these depositional and erosional periods were minor interruptions.

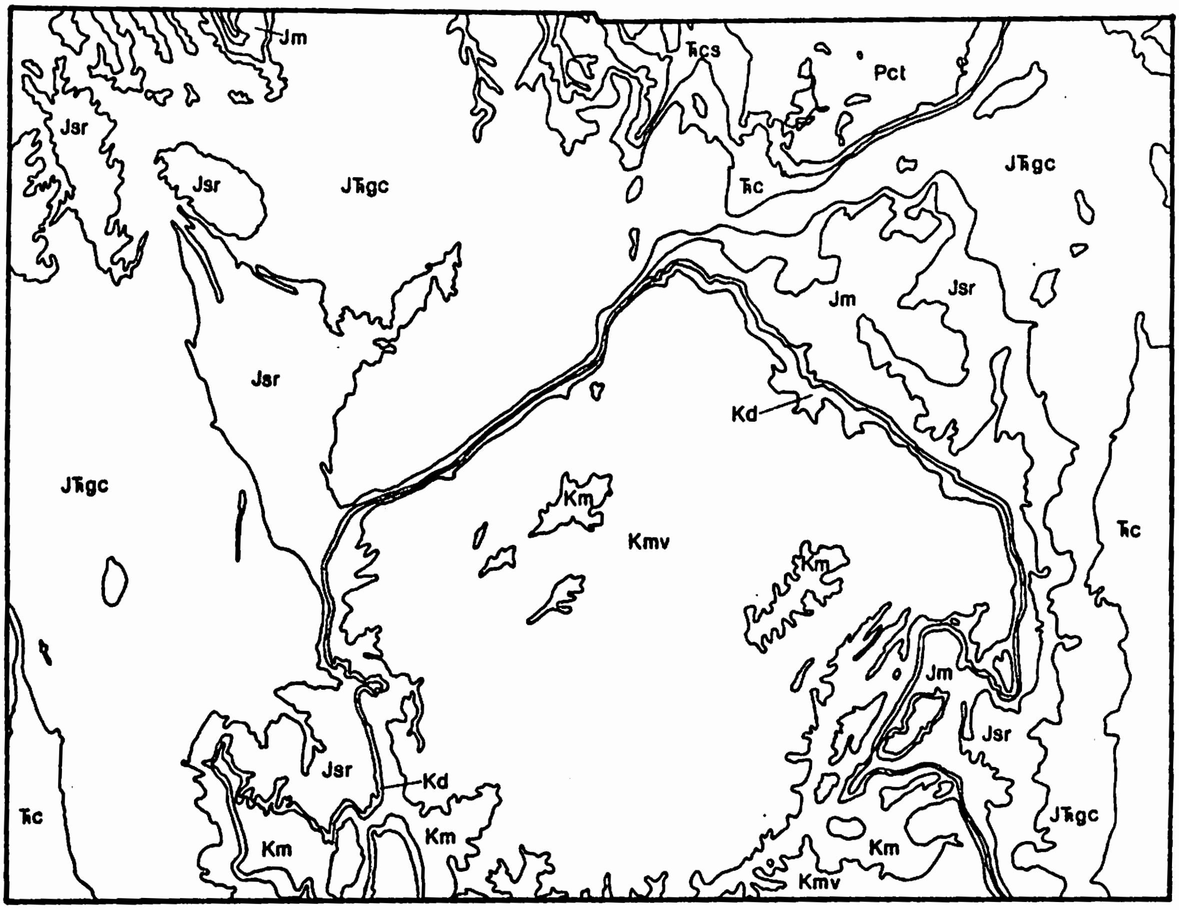
A more recent study of prehistoric climate was done by Jeffrey S. Dean of the Tree-Ring Laboratory at the University of Arizona and is being incorporated into the decadic rainfall curves by the Southwestern Anthropological Research Group (Sylvia Gaines, personal communication). Using rainfall data compiled from tree rings, Dean computed standard deviations about the mean rainfall figure for 10-year intervals between A.D. 700 and A.D. 1500 on Black Mesa. Dean's data are much more detailed than those of Karlstrom et al. (1976). For example, where they suggest a winter-dominant rainfall regime with increased effective moisture from A.D. 875 to A.D. 1150, although the overall pattern may be one of increased moisture, Dean's data indicate numerous fluctuations within that period. From these data it appears that fairly long-term droughts occurred in the periods A.D. 700-725, A.D. 740-770, A.D. 865-885, A.D. 985-1015, and 1130-1190, the latter being the longest.

Geology

The following description of the geology of Black Mesa and the surrounding area is more detailed than the previous environmental summaries because it is central to the theme of this study. Information for this section is drawn primarily from the work of Eldred D. Wilson (1962), Beaumont and Dixon (1965), and Richard F. Wilson (1974).

Mesaverde Group

Black Mesa is composed of sedimentary rock, with the youngest rock capping the mesa and the older ones beneath and radiating from it (Hack 1942). The Mesaverde Group (Kmv-see Figures 3 and 4), which caps Black Mesa, was divided into three units (in descending order, Yale



Key:

Kmv = Mesa Verde Group

Km = Mancos Shale

Kd = Dakota Sandstone

Jm = Morrison Formation

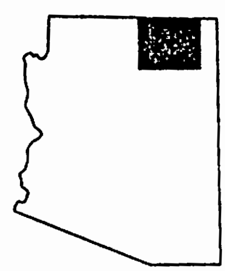
Jsr = San Rafael Group

JTRgc = Glen Canyon Group

TRc = Chinle Formation

TRcs = Chinle Formation

Pct = Cutler Formation



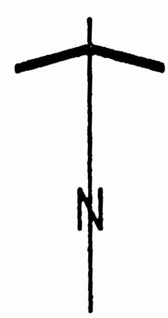


Figure 3. Geologic map of Black Mesa and vicinity.

System	Series	Group	Stratigraphic unit
Cretaceous	Upper	Mesaverde	Yale Point Sandstone
Cretaceous	Upper	Mesaverde	Wepo Formation
Cretaceous	Upper	Mesaverde	Toreva Formation
Cretaceous	Upper		Mancos Shale
Cretaceous	Lower(?) and Upper		Dakota Sandstone [1]
Cretaceous	Lower		Burro Canyon Formation
Jurassic	Upper		Morrison Formation
Jurassic	Upper		Cow Springs Sandstone
Jurassic	Upper	San Rafael	Bluff Sandstone
Jurassic	Upper	San Rafael	Summerville Formation
Jurassic	Upper	San Rafael	Todilto Limestone
Jurassic	Upper	San Rafael	Entrada Sandstone
Jurassic	Middle	San Rafael	Carmel Formation
Jurassic and Triassic(?)		Glen Canyon	Navajo Sandstone
Triassic(?)	Upper	Glen Canyon	Kayenta Formation
Triassic(?)	Upper	Glen Canyon	Moenave Formation
Triassic	Upper	Glen Canyon	Wingate Sandstone
Triassic	Upper		Chinle Formation (excluding Shinarump Member)
Triassic	Upper		Shinarump Member of the Chinle Formation

Figure 4. Geologic strata for Black Mesa and vicinity (from Cooley et al. 1969:A8-A9).

Point Sandstone, Wepo Formation, and Toreva Formation) by Repenning and Page (1956). The three formations of the Mesaverde Group represented on Black Mesa generally are older than the typical Mesaverde Group of southwestern Colorado and were deposited during the Upper Cretaceous (Beaumont and Dixon 1965).

The uppermost stratigraphic unit, Yale Point Sandstone, is present today only on the northeast portion of Black Mesa. It may be up to 90 m thick and is light-colored cliff-forming sandstone of marine shore origin. The Wepo Formation consists of gray siltstone, mudstone, sandstone, and coal originating from stream action and marshlands. It ranges in thickness from 90 to 230 m (R. F. Wilson 1974) and is the source of coal for Peabody Coal Company's mining operation on Black Mesa. The Wepo Formation grades into the Toreva Formation beneath it, with the gradual change representing "a change from a marine near-shore depositional environment to a lagoonal and fluviatile environment" (Beaumont and Dixon 1965:A16-17).

The Toreva Formation ranges in thickness from 42 to 100 m and is composed of three members: (1) a lower cliff-forming sandstone of marine shore origin; (2) a middle coal-bearing layer of siltstone, sandstone, and mudstone; and (3) an upper cliff-forming sandstone of fluvial and marine short origin interspersed with marine shale (R. F. Wilson 1974). The Toreva sandstones generally are fine-grained except for a few lenses of coarse-grained sandstone that contain fragments of granite (Beaumont and Dixon 1965). The Toreva grades into the Mancos Shale. Between the two is a 3 to 15 m thick area in which sandstone is interbedded with shale.

Mancos Shale

The Mancos Shale (Km), which also dates to the Upper Cretaceous, ranges from 145 to 235 m in thickness. It is composed of slope-forming grayish mudstone and siltsone of marine origin (R. F. Wilson 1974). Selenite (gypsum) is common in the Mancos Shale, and thin beds of bentonitic clay have been noted in the lower part (Beaumont and Dixon 1965).

Dakota Sandstone

The Mancos Shale grades into the Dakota Sandstone (Kd), which is from 15 to 45 m in thickness and caps the bench of Black Mesa. It dates to the Lower and Upper Cretaceous and has been divided into three members, which are: (1) a lower cliff-forming sandstone member; (2) a slope-forming carbonaceous shale member of lagoonal origin; and (3) an upper sandstone member of probable beach origin (R. F. Wilson 1974). Within this beach layer of the Dakota sandstone is an oyster (Gryphaea newberryi) death-bed layer containing millions of fossilized shells (Beaumont and Dixon 1965). The Dakota Sandstone was deposited on an irregular erosional surface cut into the Morrison Formation beneath.

Morrison Formation

The Morrison Formation (Jm) has been divided, in ascending order, into four members: Brushy Basin, Salt Wash, Recapture, and Westwater Canyon. Only the Westwater Canyon and Recapture Members outcrop on Black Mesa (Schafer et al. 1975). However, the Brushy Basin Member may be present along the northeast flank of Black Mesa (Harshbarger et al. 1957). The Westwater Canyon Member, a cliff-forming gray to yellow sandstone and mudstone, is of fluvial origin. It may be as much as 90 m thick in certain areas but is only 8 to 11 m thick at the southern end of Long House Valley. Below this unit is the Recapture Member, which is more than 180 m thick at the northern end of Black Mesa and about 90 m thick at the southern end of Long House Valley. It is a slope-forming unit also of fluvial origin and contains a mixture of lenses of reddish sandstone and sandy mudstone (R. F. Wilson 1974).

San Rafael Group

The light gray slope to cliff-forming sandstone at the base of Black Mesa is the Cow Springs Sandstone. It was formed from windblown sand during the Middle and Upper Jurassic and is the uppermost unit of the San Rafael Group (Jsr). The Cow Springs Sandstone is the lowest visible stratigraphic unit on Black Mesa; it is covered by alluvium in Long House Valley and at Marsh Pass.

The two units of the San Rafael Group immediately beneath the Cow Springs Sandstone are the Summerville Formation and the Entrada Sandstone. They are covered in many areas by sand, alluvium, and landslide debris and where exposed often are difficult to distinguish. The Summerville Formation is "a soft reddish-orange very fine grained silty sandstone" (Beaumont and Dixon 1965:A11). The Entrada Sandstone is reddish-orange, very fine grained, clayey, silty sandstone and sandy siltstone. In addition to the difficulty in distinguishing the Entrada from the Summerville, the contact between the Entrada and the Carmel Formation, below, is not readily observable.

The Carmel Formation of Middle and Late Jurassic age is "composed principally of reddish-orange-brown sandy and silty shale and siltstone with thin interbeds of sandstone . . . the sandstone is composed mainly of very fine grained to medium grained quartz, but also includes small amounts of pink chert, weathered feldspar, and dark minerals" (Beaumont and Dixon 1965:A8). In only a few places within the study area is the contact between the Carmel and underlying Navajo Sandstone distinct. One of these places is a high, gravel-capped terrace remnant called Middle Mesa which is about 55 km southwest of the Black Mesa study area.

Glen Canyon Group

The Navajo Sandstone, of Late Triassic age, is the uppermost unit of the Glen Canyon Group (J $T_R$gc). This massive cliff-forming light brown to orange cross-bedded sandstone is highly visible as the cap of Skeleton Mesa and the slick rock patches of the lower slopes. It contains thin beds of lenticular gray cherty limestone and is about 215 m thick at Kayenta and Marsh Pass. Navajo Sandstone "is of eolian origin deposited by wind blowing from the north and northwest" (R. F. Wilson 1974:201). It is well known for forming large alcoves in which the prehistoric Marsh Pass and Tsegi Canyon cliff dwellings are found.

There is a sharp contact between the Navajo Sandstone and the underlying Kayenta Formation. The latter, also of the Glen Canyon Group, is a slope-forming very-fine- to medium-grained sandstone interbedded with lesser amounts of clay shale. It is grayish red or pale red in color. It is 41 m thick in the Kayenta area and 61 m thick at Marsh Pass.

The Kayenta Formation rests on the Lukachukai, the uppermost Member of the Wingate Sandstone, also of the Glen Canyon Group.

> South of Laguna Creek the Wingate consists of two members: the Rock Point and the overlying Lukachukai. North of Laguna Creek, however, the Wingate consists only of the Lukachukai and the Rock Point is treated as the Church Rock Member of the Chinle. The Lukachukai Member consists of resistant cliff-forming, thick-bedded, cross stratified reddish-brown sandstone composed mostly of fine- to medium-grained quartz that contains scattered coarse grains throughout (Beaumont and Dixon 1965:A6).

It is 87 m thick near Kayenta and 60 m thick at Marsh Pass. "The Lukachukai Member is of eolian origin, deposited by winds blowing from the northwest" (R. F. Wilson 1974:199).

Chinle Formation

The Chinle Formation ($T_{R}c$) ranges in thickness from 320 to 425 m and has been divided into a number of members, all believed to be of fluvial origin. In Monument Valley, five members are recognized and in ascending order are: Shinarump, Monitor Butte, Petrified Forest, Owl Rock, and Church Rock, all dating to Triassic age. Only the upper three members are exposed near the study area, and these are the lowest stratigraphic units visible in the area.

The Church Rock Member consists of siltstone, mudstone, and thin to medium beds of very-fine-grained sandstone and silty sandstone. It is brownish red except for small leached white spots and streaks. In the Kayenta area it is 60 m thick. Any depositional break that occurred between the Church Rock Member and the Owl Rock Member, beneath, probably was insignificant. The base of the Church Rock Member is placed above the limestone-pebble conglomerate of the Owl Rock Member.

The Owl Rock Member is a "reddish-brown silstone and mudstone with lesser amounts of greenish-gray claystone, limestone and limestone-pebble conglomerate" (Beaumont and Dixon 1965:A5). Near Kayenta this member is 46 m thick.

The lowest stratigraphic unit exposed in the area is the Petrified Forest Member of the Chinle Formation. It is visible only in a small area north of Laguna Creek and in two places north of the Tsegi trading post. It is slope-forming and consists of red, purple, and greenish-gray bentonitic claystone, clayey sandstone, and mudstone. It is about 154 m thick on the flanks of Skeleton Mesa, the area just north of Laguna Creek.

Igneous Rocks

In addition to the sedimentary rocks, there also are some igneous rocks in the area.

> Three volcanic necks and a group of igneous dikes occur along the north edge of the area and in the southeastern part. These igneous bodies are of Tertiary age and belong to two main centers of igneous activity: the Monument Valley and Hopi Buttes volcanic fields (Beaumont and Dixon 1965:A17).

Included in this category are Black Rock (Standing), located 3 km east of Kayenta, Church Rock, about 13 km east of Kayenta (both of which are classified as minettes), and Porras Dikes, about 8 km east of Kayenta.

The geologic strata described above cover most of northeastern Arizona and the Four Corners area. For this reason, many of the sources, although not the specific outcrops, of chipped stone to be described in the following section should be of interest to others working in the region. In order to locate outcrops of material in other areas within the region, detailed geologic maps should be inspected for strata producing specific raw materials, and the field observation techniques outlined below should be followed.

Chipped Stone Raw Material Source Survey

Methodology

A chipped stone raw material source survey, conducted intermittently by J. P. Schafer of USGS and me, began during the summer field season of 1976 and continued through the summer of 1978. Briefly, the first summer's work focused on resources available on Black Mesa and in the immediate vicinity; the second, on sources at greater distances, including the Four Corners area and Cameron; and the third, on information more specifically relating to possible obsidian sources in Colorado and northwestern New Mexico.

The success of this survey can be attributed largely to the detailed knowledge of the study area possessed by J. P. Schafer that was accumulated over several years of research on and around Black Mesa. The survey was accomplished partially through an extensive examination of the literature on the geologic strata of the area and by field checking "likely" spots. "Likely" spots within formations with the potential to yield chippable materials, as described in the literature, usually were recognized in the field as being, or being associated with, rock more resistant to weathering than the ubiquitous sandstones of the area. For example, limestone, with which chert usually is associated, will produce fairly flat ridge tops rather than the rounded hill tops that sandstones produce. In addition, the hardness of gravels (which include chert, quartzite, jasper, chalcedony, etc.) allows sunlight to be reflected from their surfaces. Both of these phenomena can be recognized at a distance (J. P. Schafer, personal communication). Intensive study of the lithic artifacts found on Black Mesa sites aided in the search for sources, as did discussion with Marilyn Collyer, research associate at Mesa Verde National Park, Grant Heiken, research scientist at Los Alamos, and Gene Foushee, geologist and proprietor of Recapture Lodge, Bluff, Utah. The results of the survey, including material descriptions, will be presented below. (Source locations are illustrated in Appendix A.)

Raw Materials

Baked Siltstone. The first objective of the survey was to identify materials available on Black Mesa. These occur primarily in the Wepo Formation which caps Black Mesa and upon which the majority of sites are located. Although the consensus prior to this source survey was that chipped stone raw materials, of necessity, were imported to the mesa, a single local type was recognized (Gumerman et al. 1972). This type is white baked siltstone or clinker, which is siltstone that has been naturally thermally altered by fires that spread along coal seams.

The material occurs in a softer, inferior form in a variety of colors--notably pink, gray, and yellow, depending upon iron content. The colorful variety occurs in a multitude of localities across Black

Mesa and is used widely today for gravel. Although the colored variety certainly was visible to earlier archaeologists, a limited interest in lithic artifacts may have caused its utility as a chipped stone raw material to go unnoticed.

Both types of the material fracture naturally from layers exposed in the Wepo Formation, in which the majority of coal on Black Mesa occurs. Often they exhibit pot lids (spalls) that result from poorly controlled natural heating conditions (Purdy 1974). In addition, the ongoing natural fracture process results in an absence of weathered cortex on the material as well as naturally caused "flake scars." These combine to cause difficulties in studying the stage of manufacture that these "flakes" represent.

The material was collected prehistorically either in large chunks or in small, expediently useful pieces. The white baked siltstone is available in only a few areas and occurs in layers a few centimeters thick; man-made flakes of white baked siltstone almost always are extremely small. When the limited availability of the white baked siltstone is contrasted with the great quantities of the colored varieties, the white baked siltstone appears to have been the preferred type, since it occurs in high frequencies at many sites. The colored variety appears to be softer than the white type and perhaps, as a result, only a few crudely chipped bifaces of the former have been found, whereas the latter often are found in the form of finely chipped projectile points. Several flakes and naturally fractured pieces of this material have been found on sites in the Long House Valley, located to the north at the base of Black Mesa (Czaplicki 1977). The transport of this material seems more significant when chert outcrops, which are in closer proximity to Long House Valley sites, are taken into consideration.

Wepo Formation petrified wood. While inspecting a source of the white baked siltstone along Dinnebito Wash, several large blocks of a coarse-grained petrified wood were located. These were secondarily deposited, so it was not until a bedrock source was located (near site D:11:1161) that it became certain that this material is available on the mesa.

The type of petrified wood found on Black Mesa differs considerably from that in the Petrified Forest National Monument area. The Black Mesa petrified wood is black and gray, very coarse-grained, and often has quartz veins and quartz crystals in it. It has only poor conchoidal fracture but is extremely tough, which may account for its frequent prehistoric use as hammerstone material.

Petrified wood can be obtained in the Black Mesa vicinity, near Kayenta and at the base of Skeleton Mesa; near Cameron; near Ganado; and in the Petrified Forest National Monument (Sidney R. Ash, personal communication). All of these other source localities occur in the Petrified Forest Member of the Chinle Formation. The petrified wood in the Chinle Formation at the base of Skeleton Mesa more closely resembles that from the Black Mesa Wepo Formation than it does other Chinle Formation petrified wood.

Dr. Sidney R. Ash, chairman of the Geology Department at Weber State College, Utah, and authority on fossil plant material, examined some of the Black Mesa petrified wood artifacts and source samples. Dr.

Ash's analysis supported the majority of the identifications made by the author. However, according to Dr. Ash, ". . . we can never be sure in at least most cases what the source of petrified wood is when it has been removed from the formation in which it occurred" (letter communication, September 24, 1979). None of the specimens showed structural characteristics of the angiosperms (Random House 1978:31 definition: "a plant having its seeds enclosed in an ovary") that developed during the Cretaceous (and would indicate origin in the Wepo or some other Cretaceous Formation). Thus, Dr. Ash had to rely upon color, preservation, and general appearance to make his identifications.

Given the uncertainties in even the microscopic identification of these materials, it is necessary for analytical purposes to assume that the coarse-grained petrified wood was obtained locally. Association of the vitreous petrified wood with the Chinle Formation was somewhat more secure and included the possibility of origin in the Petrified Forest National Monument area. Vitreous petrified wood is, therefore, assumed to have been available only at some distance from the mesa.

Sandstone. Sandstone, abundant in all areas of the mesa, sometimes was used as a chipped stone raw material. Surprisingly, often it evidences clear flake characteristics. Some of the sandstone debitage may have resulted from ground stone rather than chipped stone manufacture, but, until there is a basis by which to differentiate the two manufacturing processes, sandstone debitage will be included with the chipped stone.

Baked sandstone. In certain areas fires in coal seams have altered sandstone outcrops thermally. The heating toughens the material considerably, apparently by fusing the sand grains. Thus, baked sandstone resembles quartzite, which is metamorphosed sandstone. This material often was used as hammerstones, probably owing to its toughness.

Fused material. Coal fires, in some areas, have been intense enough to cause siltstone layers and possibly also some sandstone outcrops to become molten and, upon cooling and rehardening, to become vesicular. This fused material sometimes is found on prehistoric sites but rarely is suitable for knapping.

Siderite and iron concretions. Siderite, in nodules and layers, is available in massive form in the Wepo Formation. Siderite is an iron carbonate that is brittle with uneven to conchoidal fracture. Its hardness is only 3.5 to 4, compared with chert's hardness of 7 (Sinkankas 1964). Calcite often is found adhering to siderite and sometimes appears at prehistoric sites. Iron concretions also are available on the mesa and sometimes are found on sites but were used infrequently for chipped stone manufacture.

Quartzite and vein quartz. The Toreva Formation is the uppermost stratigraphic unit along part of the western escarpment of the mesa. Resting on the Toreva Formation is a secondary deposit of quartzite and vein quartz cobbles and pebbles of chert. The origin of these gravels is an unknown stratigraphic unit that has eroded away completely, leaving the more resistant rock, the gravel, behind. Chert is available in these gravels; however, the small sizes of the pebbles there today suggest that, even prehistorically, the sizes were below the standard suitable for knapping and certainly too small to have produced many of the flakes of this material observed on sites. Although it cannot be verified empirically, it will be asssumed that this area provided a source for quartzite and vein quartz, but that it was not an important source of chert gravels. Further investigations during the summer of 1981 revealed additional small but chippable chert gravels at the base of the north side of Black Mesa.

Purple conglomerate sandstone. Along with the search for chipped stone raw material sources, the origin of a purple conglomerate sandstone, often used for ground stone manufacture, was sought. Although it never was located in outcrop, it has been recognized in landslide materials from the Toreva Formation and is believed to be the same coarse-grained sandstone mentioned in published descriptions of the Toreva Formation (Beaumont and Dixon 1965).

Silicified siltstone. The Mancos Shale, which lies beneath the Toreva Formation, has yielded no known chipped stone raw materials in the Black Mesa area, but a silicified siltstone available in it at Mesa Verde National Park appears quite frequently in artifact collections there (Marilyn Collyer, personal communication). This material at Mesa Verde may have provided the assemblage equivalent of the abundant thermally altered materials available on Black Mesa in the Wepo Formation.

Mesa Verde and Black Mesa are similar stratigraphically with the exception of the absence of the Wepo Formation and concomitant coal seams at the former. An inspection of the collections at Mesa Verde and discussions with Marilyn Collyer served to point out some similarities in the collections from the two areas and suggest potential sources in the formations common to both areas.

"Fracture-line" chert. Beneath the Mancos Shale, at both Mesa Verde and Black Mesa, is the Dakota Sandstone. The uppermost layer of the three within the Dakota Sandstone is a sandstone layer of probable beach origin. Within this beach layer is an oyster death bed zone containing millions of fossilized shells, some of which are found at Black Mesa sites on the mesa top, indicating human transport. The layer of beach origin also contains some pebbles of chert. There is a certain chert found on Black Mesa sites referred to as "fracture-line" due to its iron-stained cleavage planes on otherwise milky translucent material. This same chert was identified in the Mesa Verde collections and originates in the Dakota sandstone pebble layer at Mesa Verde. However, the chert pebbles located by the survey in the same layer around Black Mesa appear too small to have been useful.

"Creamy opaque" silicified claystone. Beneath the Dakota Sandstone, also in both the Black Mesa and Mesa Verde areas, is the Morrison Formation. The two units of this formation in the Black Mesa area, the Westwater Canyon and Recapture Members, have not been found to yield potential chipped stone raw material sources. However, the Brushy Basin Member, which outcrops in the Four Corners area and farther north into southeastern Utah and southwestern Colorado, has been found to yield what will be referred to as "creamy opaque" material. The material actually is a silicified claystone that usually is light blue or green but also may have bands of pink, gold, or brown.

Prehistorically this "creamy opaque" material comprised a large proportion of the assemblages at both Mesa Verde and Hovenweep and was used in lesser quantities at Chaco Canyon, Salmon Ruin, and Black Mesa. Hovenweep seems to have the widest representation of the color range, whereas Black Mesa and Chaco Canyon mainly have the greenish variety and Salmon Ruin mainly has the tan variety (Catherine Cameron, letter communication, November 4, 1980). This material often was used to make tchamajillas, although none have been found on Black Mesa. The material outcrops in many places around the San Juan Basin. Known outcrops include an area near San Ysidro (Catherine Cameron, letter communication, November 4, 1980); several hundred meters due north of the Four Corners Monument (Marilyn Collyer, personal communication which subsequently was field verified); and near the confluence of the San Juan River and Montezuma Creek in Utah (Gene Foushee, personal communication which subsequently was field verified). One geological reference (Harshbarger et al. 1957) suggests that the Brushy Basin Member may outcrop along the northeast side of Black Mesa, but field investigations have not located this material at that locality.

Gravels. The Cow Springs Sandstone at the base of Black Mesa has been found to yield no potential chipped stone raw materials. However, White Mesa, approximately 48 km to the west and named for the white appearance of the Cow Springs Sandstone, has some secondarily deposited gravel. This gravel contains chert, quartzite, and petrified wood and rests on the Dakota Sandstone that caps the mesa.

Approximately 55 km to the southwest of the study area is a high terrace remnant called Middle Mesa. At the base of the mesa is Navajo Sandstone, which will be discussed shortly. Above it, for about 10 m, is the Carmel Formation upon which a gravel cap is located. This gravel, which is about 5 m thick and strongly cemented by caliche, contains chert, quartzite, quartzitic chert, petrified wood, jasper, and chalcedony. Also observed scattered around Middle Mesa and at a site there were many flakes and some cores of chert from the Navajo Sandstone. These Navajo chert materials must have been transported to the top from sources near the base of Middle Mesa. Although the major gravel sources appear to be at distances in excess of 40 km from the mesa, its availability, even in limited quantities, at the base and on top of the mesa requires that it be considered with the intermediate materials rather than the distant imports.

Outcrops of the Carmel and Entrada Formations near Black Mesa have not yielded chipped stone raw materials. However, both to the northeast and southwest of the mesa, gravel sources have been found in either or both of these formations. The contact beween the Carmel and Entrada Formations is difficult to distinguish. For this reason, no effort will be made to associate these gravels with one or the other formation. One such gravel source is located east of Kayenta and Comb Ridge, in the area around Church Rock. These gravels have been observed to contain chert, quartzite, vein quartz, quartzitic chert, and petrified wood.

In addition to the nondistinctive gray and yellow-brown chert cobbles are two distinctive chert types that have not been found elsewhere. One is a greenish-yellow, opaque, coarse-grained chert of dull luster. Much chipping debris of this material was evident at the source area. The other distinctive type is a white, translucent chert or chalcedony with pink swirls throughout, hitherto referred to as pink chert. There also was evidence of knapping of this material at the source. Beaumont and Dixon (1965) mention pink chert in association with the Carmel Formation.

Navajo chert. Within the Navajo Sandstone are chert-bearing limestone layers in such areas as the Shonto Plateau, Red Lake, and Cow Springs. The limestone beds are from 40 to 100 cm thick and usually less than 1.5 km long (Beaumont and Dixon 1965). The chert from the source area investigated was found to vary considerably. The Navajo chert near Red Lake generally is brown, red, and purple and occurs as thin, badly fractured lenses (about 1 to 5 cm thick) in the limestone matrix. None of the material observed at the source was suitable for knapping. A similar, unusable, thin, fractured black chert lens was found in a limestone layer near the Betatakin campground. Elsewhere on the Shonto Plateau, nodules of opaque white chert were found. A source of pebbles of Navajo chert along S.R. 89 (the road to Page) yielded small, but usable, pebbles of excellent quality maroon and brown chert. The best source known of Navajo chert is located on the first knoll north of the Cow Springs trading post. The chert layers at this locality were observed to exceed 35 cm in thickness and exhibited extensive evidence of use as a source of raw material. A variety of colors was observed, including gray, black, red, blue, and purple.

Owl Rock chert and purple-white chalcedony/chert. The Chinle Formation, which is several stratigraphic units below the Navajo Sandstone, is the next in the area to yield chippable materials. Chert material from the Owl Rock Member, the uppermost member of the Chinle Formation, was located first in a gravel quarry near Cameron on an excursion to examine gravels from the Little Colorado River. At that time it was only of minor interest because a material from such a distant source was not expected in quantity on Black Mesa sites. Analysis of artifacts from sites excavated during the summer of 1976 proved it to be the most frequently represented chert material. An inspection of geologic maps for the area around Black Mesa indicated outcrops of the Owl Rock Member both at the base of Skeleton Mesa and west of Kayenta; both of these outcrops were found to contain chert.

Owl Rock chert has been observed in two principal varieties. One is silicified limestone that contains small deposits of pure chert. It is red or purple and green in color and may contain fossils. The combination provides knapping material free of fault lines even with the transition from one material to the other. The other type is a purplish-white or smoky-white translucent chalcedony that sometimes grades into a more purple chert. Outcrops at the base of Skeleton Mesa were observed to have more of the silicified limestone with chert inclusions, and those near Kayenta produced more the of the translucent purplish-white chalcedony/chert.

Chinle Formation petrified wood. Beneath the Owl Rock Member and also cropping out at the base of Skeleton Mesa is the Petrified Forest Member of the Chinle Formation. This wood originates from the same member as the petrified wood available in the Petrified Forest National Monument, which is found in small quantities on some Black Mesa sites. However, the petrified wood from this source bears a closer resemblance to the coarse-grained black-and-gray wood that outcrops in the Wepo Formation on Black Mesa. (See discussion on pp. 128-130.)

Chinle chert. An opaque red-orange chert that grades into clear chalcedony and sometimes has blue and/or yellow streaks can be found near Cameron, Arizona (Don Keller, personal communication that subsequently was field verified). It was seen in outcrops in the contact zone between the Petrified Forest Member of the Chinle Formation and an unnamed sandstone and mudstone member beneath it. This material appears in low frequencies at a few Black Mesa sites and has been identified tentatively in collections from Chavez Pass Ruin. It will be referred to as Chinle chert.

The term *Chinle chert* has appeared in the literature (Warren 1967) for the Chaco Canyon area, but further research indicates that the material referred to as Chinle chert is really from Paleozoic rocks near Mount Sedgewick in the Zuni Mountains. It is a yellowish-brown opaque chert with black spots that grades into red jasper-like material (Catherine Cameron, letter communication, November 4, 1980). This material bears no resemblance to the Black Mesa Chinle chert. However, Laguna chert and Zuni Wood, both from the Chaco Canyon material classification, developed by Warren (1967) do bear quite a close resemblance to the Black Mesa Chinle chert.

Volcanic materials. Although no source exists in the immediate vicinity of Black Mesa, low frequencies of volcanic materials have been observed on sites. Basalt is virtually nonexistent on Black Mesa. However, obsidian, particularly a glossy black variety, is slightly more common. On the basis of intrusive ceramics from Mesa Verde, collections there were inspected for similar obsidian, but to no avail. The material from sites there is also very scanty, and what little of it there is, is light gray and almost transparent. The source of obsidian at sites there was also unknown.

Because it is recognized that visual source assignment for obsidian is tenuous and the material on Black Mesa bears a close resemblance both to that available near Flagstaff and that available in the Jemez Mountains of northwestern New Mexico, chemical characterization of the obsidian was done. Lee Sappington of the University of Idaho performed X-ray fluorescence on 40 artifacts from Black Mesa sites and one from Red Mesa in the Mesa Verde area. The vast majority of the Black Mesa obsidian originated in the San Francisco volcanic field near Flagstaff, at the Government Mountain and Crater Lake sources in particular. A few pieces from earlier sites (A.D. 900-1000) were from Superior, Arizona, and Mule Creek, New Mexico. The single Mesa Verde artifact was from the Jemez Mountains, where a few but not many Black Mesa lithics also originated. Almost all of the artifacts from sites in this study are from Government Mountain. These results will be reported more fully in a future paper.

Oolitic and fossiliferous cherts. The oolitic and fossiliferous cherts have not been located as to source. They all contain either oolites, small white oval-shaped miniconcretions, or fossils. (Owl Rock chert is excluded because, although it may contain fossils, it can be identified as to source.) The vast majority of artifacts of this material have a gravel-type rolled-percussion cortex, so for distance estimates they will be grouped with the other gravels. They are maintained in a separate category because future study of the inclusions may shed light on the age of the parent rock.

Summary

In summary, 38 material types have been described and related to at least 29 different sources. Because there was such a wide variety of materials used on Black Mesa, sample sizes within each of the categories may prove too small for meaningful statistical manipulations. For the purposes of certain analyses, material types will be grouped according to distance to source. Table 5 shows the groupings of materials based upon distance to source. As can be seen from the table, the closest source for materials from several possible sources will be assumed. Two categories will be deleted from the analyses due to inadequate source information, although they are retained in the total frequency for each site. They are chert of unknown origin and unknown material.

Table 5. Raw Material Groupings Based on Distance to Source

Local	Intermediate	Distant
coarse-grained petrified wood	Owl Rock chert and purple-white chalcedony/chert	vitreous petrified wood
vein quartz	brown; white; and red, white, and blue Navajo chert	fracture-line chert
quartzite	chalcedony; brown, gray, and oolitic and fossiliferous chert gravels	Chinle chert
sandstone	quartzitic chert	creamy opaque
siderite	pink chert	obsidian
baked sandstone		basalt
iron concretions		
white, gray, pink, and yellow baked siltstone		

Prehistoric Sites

Site Recording Procedures

During the fall of 1975, the Black Mesa Archaeological Project conducted an intensive survey of approximately 130 km^2 on northeastern Black Mesa. George Gumerman was principal investigator of the project, Stephen Plog was the director, and Steven Sessions was the field director. The data base for this study is composed of the lithic artifacts collected from the 97 sites with more than 10 lithics and more than 20 sherds of the 765 prehistoric sites recorded on this survey.

Survey crews consisted of four to six persons, including a crew chief, students, and Navajos. Crew members walked approximately 20 m apart and covered a block area as if it were contiguous transects. Biodegradable markers (toilet paper) were used to indicate the area already traversed to ensure that coverage was complete.

Site definition was a mixture of intuitive and quantitative criteria; an effort was made to maximize the strong points of each. Rather than using an arbitrary artifact density criterion for site determination and site boundary definition, crews were asked to intuitively decide and to make explicit in quantitative terms the justification of their decisions.

Although both prehistoric Anasazi and historic Navajo sites were recorded, this discussion will deal only with recording methods used for the prehistoric sites. Each site was accorded an individual number indicating, by letter, portion of the state (all sites on the survey received the letter D); by number, area within the larger area; and by number, cumulative number of sites found within that area. Site numbers for sites larger than 10 four-meter squares began at 1; site numbers for sites smaller than 10 four-meter squares began at 1,000. The site number was carved into a datum stake placed at the approximate site center, to which all measurements and locations on the site were related.

Site boundaries were defined in eight directions from the datum, beginning at 0 degrees and moving clockwise at 45 degree intervals. The artifact density at each of the eight boundary points was recorded. When the boundaries were determined, the number of four-meter square units within the site outline was calculated. From this universe, a statistically valid systematic unaligned sample was chosen by calculating the interval between squares necessary to sample at least 10% of the site. The origin square was chosen randomly from within the first interval. Sites with greater than 200 four-meter squares had a maximum of 20 collection units, but there are only 14 of the 765 sites recorded for which there is less than a 10% sample. Sites with 10 or fewer four-meter squares were collected in their entirety within four-meter squares (Layhe et al. 1976).

All artifacts, with the exception of ground stone, were collected from each sample unit and recorded according to that provenience. Ground stone artifacts were recorded but left in place due to transport difficulties. Sites were located on 1:400 contour maps generated from aerial photos and provided by Peabody Coal Company.

This site collection technique provided a good representation of the variation and proportions of various artifact types on the sites. The random sample often was supplemented by judgmentally selected collection units in order to increase sample sizes or fill gaps in site coverage.

Site maps were produced, and detailed information on site features, location and environmental setting, and artifact densities across the site was recorded also. Site sizes varied from 1 m^2 to over 12,000 m^2, and the temporal range extended from late Archaic/Basketmaker II to late Toreva Phase.

Dating of Sites

Site dates used in this analysis are derived from a study by Hantman and Plog (1978), which emphasized ceramic attributes rather than the traditional types. The disadvantages they found with the type system include the "unquantified, inexplicit nature" (Plog and Hantman 1979:217) with which ceramic assemblages usually are assigned to ideal ceramic complexes and

> . . . the polythetic, multi-attribute nature of the types. For example, Kana-a Black-on-white, as defined by Colton (1955), has thin lines, secondary ticks as opposed to dots, zigzag lines, irregular lines, flags, and overlapping lines. The use of four or five such types necessitates the recognition for any collection of sherds of over two dozen attributes in order to make the type classifications. In addition, the use of such types involves the usually implicit assumption of strong covariation of all attributes through the life of a type, when no studies have measured the actual degree of covariation (Plog and Hantman 1979:217-218).

In addition, they found that it is frequently the case that large numbers of black-on-white sherds do not have enough diagnostic attributes to be classified in the type system. This drawback can be critical in studies of surface collections which expectably have lower frequencies of artifacts than are found in excavation collections. Finally, the attribute system allows dating within smaller intervals of time than the type system and is, thus, more useful in detailed studies of change over time.

The method used in the analysis is as follows:

> 1) the derivation of significant variables, or factors, which are sensitive to change over time; 2) the grouping of sites, on the basis of those variables, by means of cluster analysis; and 3) the testing of the validity of groups by means of a discrimnant analysis. (Read 1974; Hantman and Lightfoot 1978). The final stage in this methodology is to use the classification function of discriminant analysis to place the tree-ring dated sites into these groups, so as to assign approximate dates to them (Hantman and Plog 1978:7-8).

Design attributes employed included solid designs, hatched designs, five categories of line width, ticks, dots, isosceles triangles, and other triangles. Results were as follows:

> Using only two attribute states, the relative frequencies of sherds with hatching and with lines between six and nine mm. wide, the standard error of the residuals for the predicted tree-ring dates was thirty-four years. Using five attribute states or independent variables in the regression analysis, the standard error of the residuals was twenty years (Plog and Hantman 1979:220).

Hantman and Plog have refined their technique over a period of years, which has resulted in several sets of dates. To avoid confusion, the ones used in this study were generated in 1978-1979 and are presented in Appendix B.

Site Function and Raw Material Distribution

Recent analyses of Black Mesa lithics (Green 1978; Green, in press) have emphasized variability in the distribution of chipped stone raw materials at sites of different function. The suggestion that differences in raw material distributions may be expected at functionally distinct sites was posed first by Gary Wright:

> In this situation, one would, first of all, not expect the same lithic tool types to be present. Second, the ratio of obsidian to flint on each of these sites would expectably vary. . . . This is probably due to the tasks performed at each site, that is, the differences are functional (1969:51).

It also has been argued (Green, in press) that the distance from which the material was procured and the form in which it was procured should be related to its ultimate distribution in the site system. If nonlocal materials were brought to an area in large quantities, probably they would be taken first to habitation sites where the majority of manufacture would take place. Then, tools or utilizable flakes of the material would be transported for use elsewhere. Conversely, materials available locally would be available on demand, and evidence for their reduction into usable pieces would be expected at any type of site.

The dispersal of nonlocal tools or flakes from habitation to limited activity sites would create "noise" that must be factored out before distributional patterns related to procurement from source and interaction among sites can be understood. There is a sense, of course, in which the habitation sites can be seen as sources of the nonlocal materials for the limited activity sites. However, until secure means for relating limited activity sites back to habitation sites are developed, this avenue of investigation is blocked.

A site configuration or, to use the term loosely, a site function, variable was developed in order to categorize the sites and test for significant differences in raw material distributions across the site categories. The categories were defined arbitrarily on the basis of site size and architectural composition. Five groups were created, the first three of which had no architectural features visible on survey. Site size was used to discriminate among them; the first group of sites have areas less than 100 m^2, the second, between 100 and 500 m^2, and the third, greater than 500 m^2 in area. The fourth group includes sites with at least one, but no more than one, of any or all of the following features: roomblock, kiva, depression, pithouse, or midden. Sites in the last group have two or more of any, or all, of the individual feature types. Although arbitrary, the site breakdown is regarded as one of increasing complexity, with the smallest, least-complex sites considered limited activity sites, and the larger, more-complex ones as habitation sites.

Because such a wide variety of materials was used on Black Mesa, sample sizes within each of the raw material categories often would have been too small for meaningful statistical manipulations. Material types were grouped by distance to source; local materials are those available on the mesa, intermediate materials are available off the mesa but within a 40 km radius of the study area, and distantly available materials are those with sources at distances greater than 40 km from the study area (see Table 5).

One-way analysis of variance was the principal statistical test employed; the site-complexity variable was the independent variable, and the raw material grouping was the dependent variable. Variables tested for significant differences across the groups include measures of abundance, indices of manufacturing stages, and measures of the relative amount of use of the material groups.

The analysis demonstrated that raw material types that were available locally were used at all site types and had relatively standard proportions of use to wastage. The analysis also demonstrated that materials available at intermediate distances were carried first to habitation sites where the initial stages of manufacture took place.

The model was not able, however, to account for the pattern of distribution and use of the distantly derived material group. This group conformed more to the patterns expected for the materials available locally than for those that were nonlocal. Several explanations and/or alternate models were suggested by these results:

1. Sample sizes for these materials were too small to yield statistically reliable results.
2. Assumptions concerning the nonutility of the chert gravels available on the mesa due to size were incorrect, and the chert gravels actually were available locally. (The chert gravels at the base of the mesa were unknown at the time of this study; they were considered distant imports.)
3. The utility of these materials lies principally in their ability to produce a fine cutting edge. Transport in utilizable form would have been detrimental to such an edge, so these materials remained in their original state until actually needed. Preservation of cortex would not have been necessary for the other materials since they generally are more coarse-grained, nor would it have been possible, because, in many cases, the source material has no cortex.
4. Transport of the materials to the mesa may have been undertaken by individuals from only a few sites on the mesa. Others may have procured them from these individuals and reduced them into usable form at places near the distribution site. The distribution

corresponding to this model would have manufacturing debris mainly at limited-activity sites, but these sites should be clustered around the distribution site(s).

Because the outcome of the analysis did not completely conform to expectations, the question of limited activity sites creating "noise" in raw material distribution analysis was not fully resolved. Considering the low sample sizes remaining for testing once sites with fewer than 11 lithics are omitted and once, for dating purposes, sites with fewer than 20 sherds are omitted, the further omission of nonhabitation sites simply is not feasible. In addition, the omission of sites without surface evidence of structures would serve to leave out almost all of the sites occupied during the earliest time periods. Thus, it was determined that these sites should be included in the analysis, but the influence they have on the outcome of the analysis should be carefully monitored. (See Appendix B for site configuration groups and site dates.)

CHAPTER V

TESTING MODELS OF INCREASED INTERACTION

First Examination--Cluster Analysis

Methodology

An increase in interaction over time among Black Mesa sites has been hypothesized and will be tested by studying changes in the relative frequencies of chipped stone raw materials. The hypothesis will be examined first using release 2 of the Clustan 1C package on the Arizona State University Amdahl 470 V7 IBM-compatible computer.

> Cluster analysis is an exploratory method for helping to solve classification problems. . . . The object of a cluster analysis is to sort a sample of cases under consideration (e.g. people, or specimens) into groups such that the degree of association is high between members of the same group and low between members of different groups (Wishart 1978:1).

In this instance the intent is to determine if similar assemblages of raw materials are possessed by any group(s) of sites and, if so, to identify underlying similarities in site attributes that might have contributed to the similar raw material assemblages.

Rough contemporaneity of assemblages was determined on the basis of the dates generated by Hantman and Plog's analysis (1978; see also Chapter IV). The 21 sites that have no ceramics and thus were not given dates by the ceramic analysis are retained separately in this analysis and will be referred to as "undated sites." Sites in the second group were assigned the ceramic analysis base date of A.D. 793. Although the time span covered by sites in these two groups probably is quite large, it was considered desirable to retain these sites, believed to represent the early end of the temporal sequence, in the analysis. The remainder of the sites, dating between A.D. 800 and A.D. 1150 were divided among seven 50-year-long time periods (see Figure 5).

Locational similarities were assessed as follows. Four major drainages—Moenkopi Wash, Reed Valley, Red Peak Valley, and Dinnebito Wash—cross the study area. To facilitate discussion of spatial relationships between sites, the study area was divided into four parts based on these drainages, and the site distribution was divided among them (see Figure 5).

The Hierarchy procedure of the Clustan package was chosen to group the raw material data.

> Hierarchy starts with N clusters, each being a single individual, which are numbered according to the input order of the individuals. In each of N-1 fusion cycles the two clusters which are most similar are fused, and the resulting union cluster is labelled with the lesser of the two codes of its constituent clusters. It has been suggested that the process can be stopped when a significant drop or discontinuity in the fusion coefficient value is observed. With this procedure, such selection is left to the user, since HIERARCHY completes all N-1 fusions and permits the results to be summarized in a "dendrogram" which can be printed by procedure TREE or plotted by procedure PLINK (Wishart 1978:3).

This procedure uses variable transformations of the matrix of similarity coefficients to produce fusion hierarchy. Ward's method was chosen as the specific grouping formula because it finds minimum variance clusters.

> Ward (1963) proposes that at any stage of an analysis the loss of information which results from the grouping of individuals into clusters can be measured by the total sum of squared deviations of every point from the mean of the cluster to which it belongs. At each step in the analysis, union of every possible pair of clusters

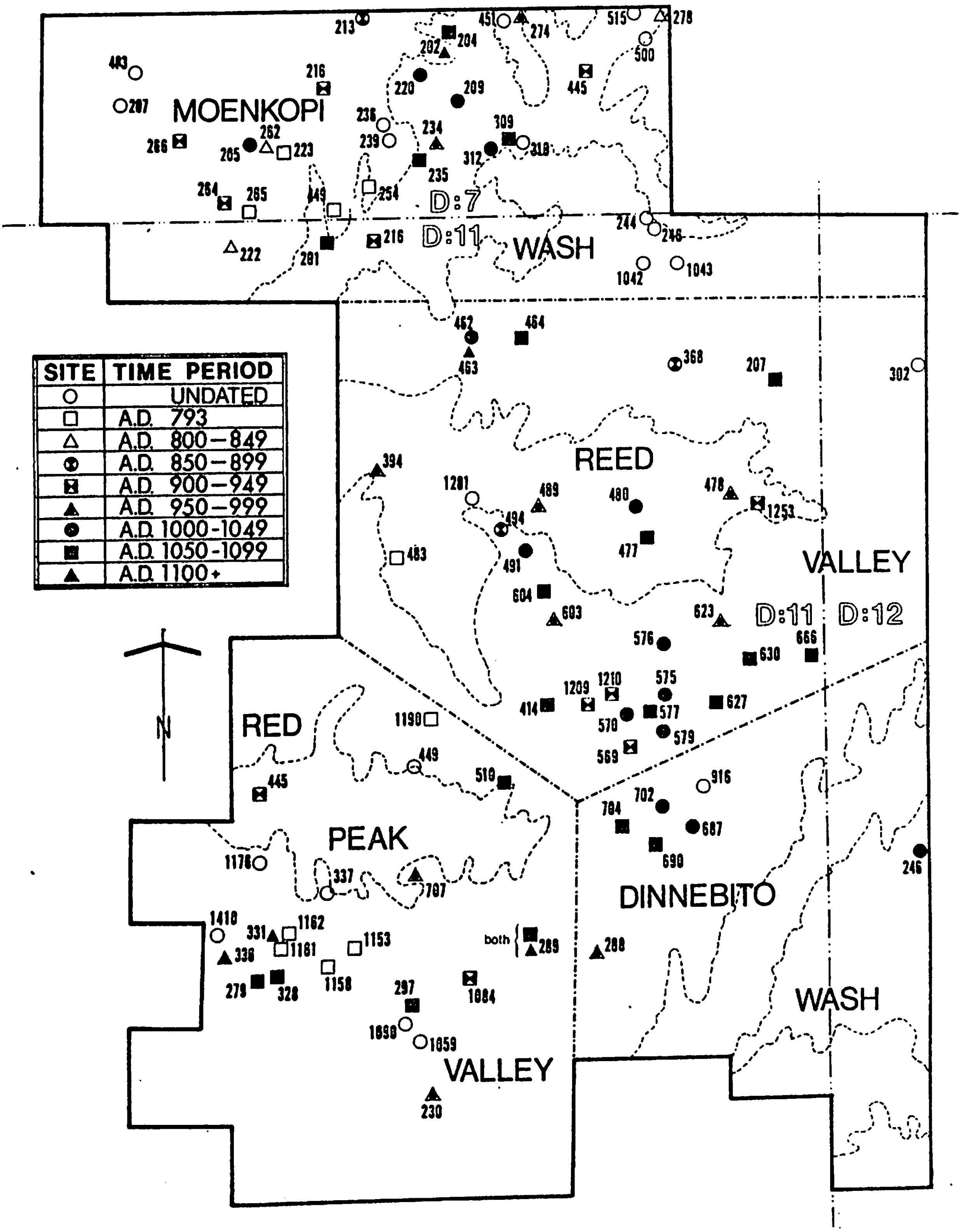


Figure 5. Distribution of sites by time period and drainage.

is considered and the two clusters whose fusion results in the minimum increase in the error sum of squares are combined (Everitt 1974:15).

The formula by which this is accomplished is:

$$\text{E.S.S.} = \sum_{i=1}^{n} x_i^2 - \frac{1}{n}(\Sigma x_i)^2$$

where E.S.S. = error sum of squares

Σx_i^2 = sum of squares of data values

$(\Sigma x_i)^2$ = square of the sum of data values

n = number of cases

The figure input for each raw material was the percent it contributed to the total assemblage at each site. Material types were grouped prior to the cluster analysis to remedy problems created by an overabundance of zero values for many of the lower frequency variables. Several of the lower frequency nonlocal materials, including obsidian, basalt, fracture-line chert, and vitreous petrified wood that did not combine readily into meaningful higher frequency groups, had to be eliminated from this stage of the analysis. Information about them will be provided where relevant (see Appendix C for complete data tabulation). For this reason combined with the elimination of the unknown category, the percentages do not add up to 100 in all cases. The raw materials used in the cluster analysis are listed in Table 6.

Three runs were performed for each cluster series. The first run included all 11 material groups. Proportions of local materials often were much greater than those of nonlocal materials, and it was

Table 6. Raw Materials Used in Cluster Analysis

Item	Material
1	Local petrified wood
2	Quartz (vein quartz and quartzite)
3	Sandstone
4	Iron (iron concretions and siderite)
5	Baked sandstone
6	Baked siltstone (all color varieties)
7	Navajo chert (all color varieties)
8	Owl Rock materials (Owl Rock chert and purple-white chalcedony/ chert)
9	Gravels (chalcedony, gray and brown cherts with rolled percussion cortices, quartzitic chert, oolitic and fossiliferous cherts)
10	Creamy opaque material
11	Chinle chert

Note. Items 1-6 are local materials, and items 7-11 are nonlocal materials.

suspected that the former class might mask the influence of the latter in cluster formation. Thus, two separate runs were performed for local and nonlocal materials.

Dendrograms (Figures 6, 10-32) were plotted, using the PLINK procedure, for each cluster analysis. Each case is labeled on the X axis with the site number (e.g., D:7:207), a letter representing the drainage in which the site is located (M = Moenkopi Wash, R = Reed Valley, P = Red Peak Valley, and D = Dinnebito Wash) and a final number from 1 to 9 representing the time periods in order from undated to A.D. 1100-1149. Ward's coefficient is plotted along the Y axis on each dendrogram. The fusion process is stopped when a significant discontinuity in Ward's coefficient occurs. Means for each raw material at sites in each cluster are presented in Appendix D. Slight discrepancies between the figures presented in the text and those in the Appendix are the result of rounding; the figures in the text are more precise.

Test Results

Cluster analysis for sites from all time periods. The first cluster analysis series was run for all 97 sites with a total of 11 grouped material variables. The fusion process for the all-materials, all-sites run was stopped at two clusters because a significant discontinuity in Ward's coefficient was observed between two clusters and one cluster (i.e., Ward's coefficient at 3 clusters = .276, at 2 clusters = .389, at 1 cluster = 2.719). The same process of cluster

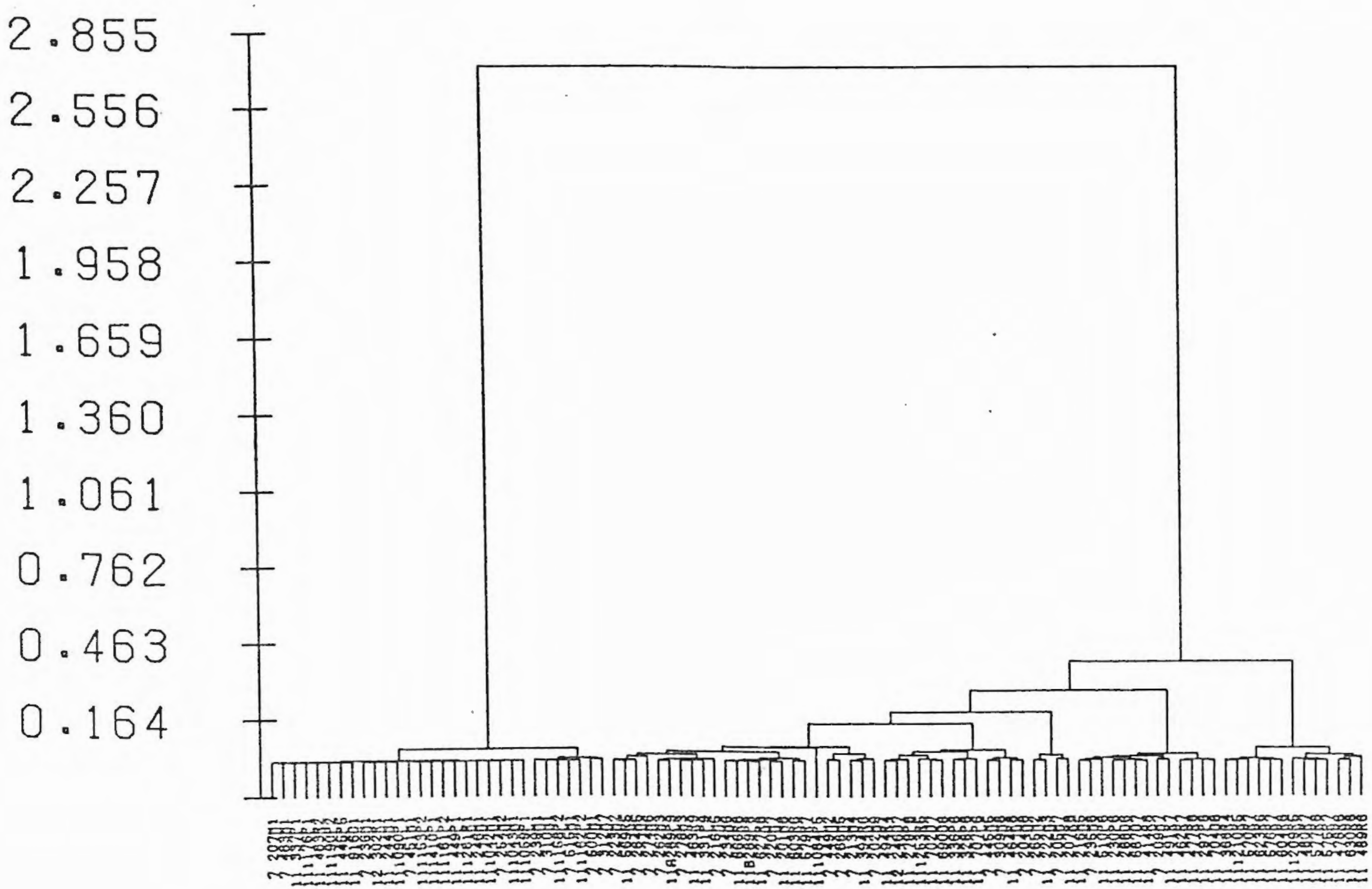
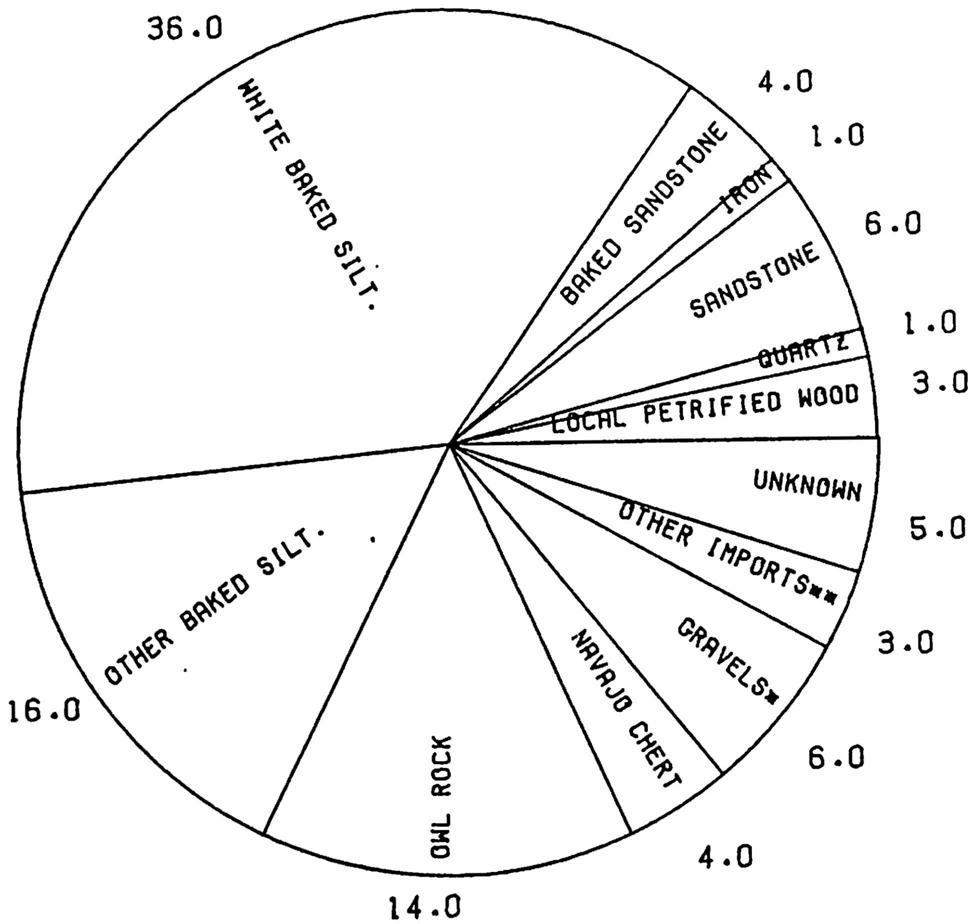


Figure 6. Dendrogram for all sites-all materials.

outcome selection was used for each run and will not be discussed further.

Cluster I (30 sites) is composed almost entirely of undated sites and those dated to A.D. 793 (see Figure 6). The principal grouping variable was baked siltstone with a mean of 91% (see Appendix D). Baked siltstone, the white variety in particular, has been linked with the Basketmaker II occupation of Black Mesa. Of the 21 sites used in this analysis that could not be dated ceramically, the five that have been excavated were established as Basketmaker II sites by independent dating techniques (i.e., radiocarbon and/or tree-ring analysis). Three of the 10 sites in this analysis dated ceramically to A.D. 793 have been excavated, and two of them are Basketmaker II sites as well. The third has tree-ring dates that span the period from A.D. 750 to A.D. 800. Thus, whenever a site with an abundance of baked siltstone and a paucity of ceramics has been excavated, it has been demonstrated to date to Basketmaker II times or at least to an early date in the sequence by means other than the singular use of this material. For the purposes of this analysis, so as not to eliminate the earliest sites from the analysis due to an absence of ceramics, the assumption will be made that the remainder of the undated sites (all of which have no ceramics and high percentages of baked siltstone) are Basketmaker II sites.

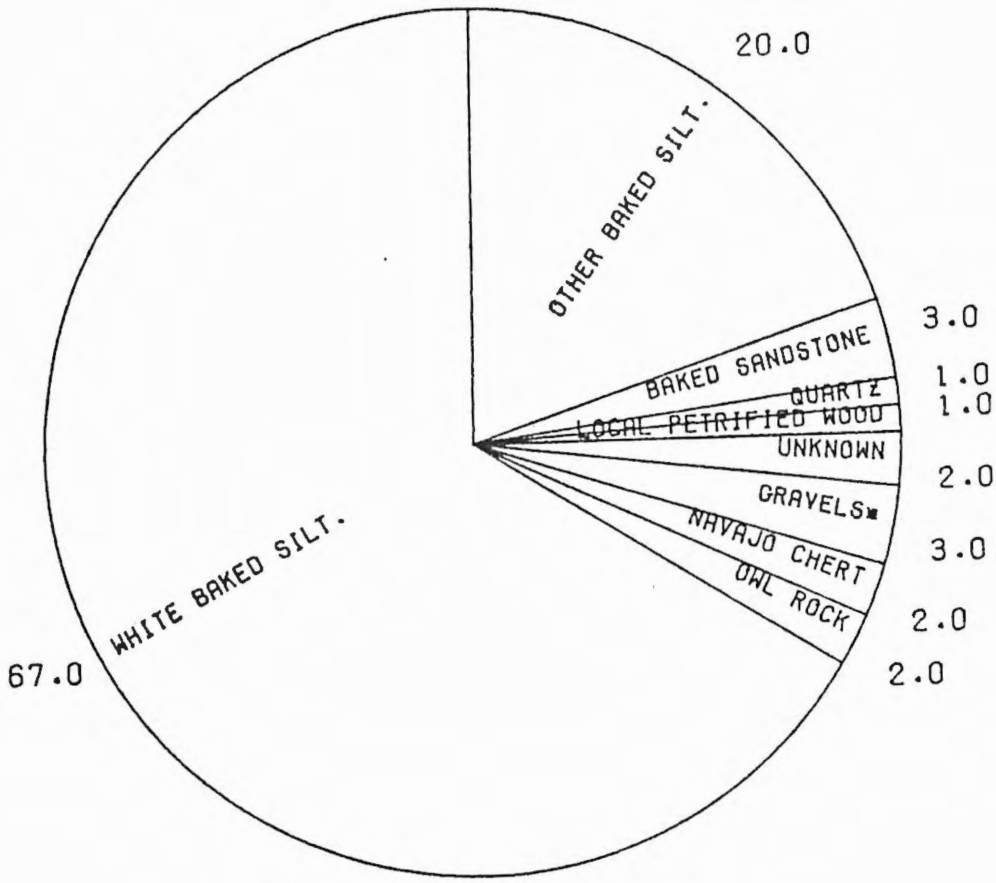
Figures 7-9 are pie diagrams that graphically depict this focus on white baked siltstone during the earliest occupation of Black Mesa. Figure 7 illustrates the percentage of each raw material for all time, and Figures 8 and 9 illustrate the same information for pre- and post-A.D. 800, respectively.



* chalcedony; gray, brown, quartzitic, and oolitic cherts

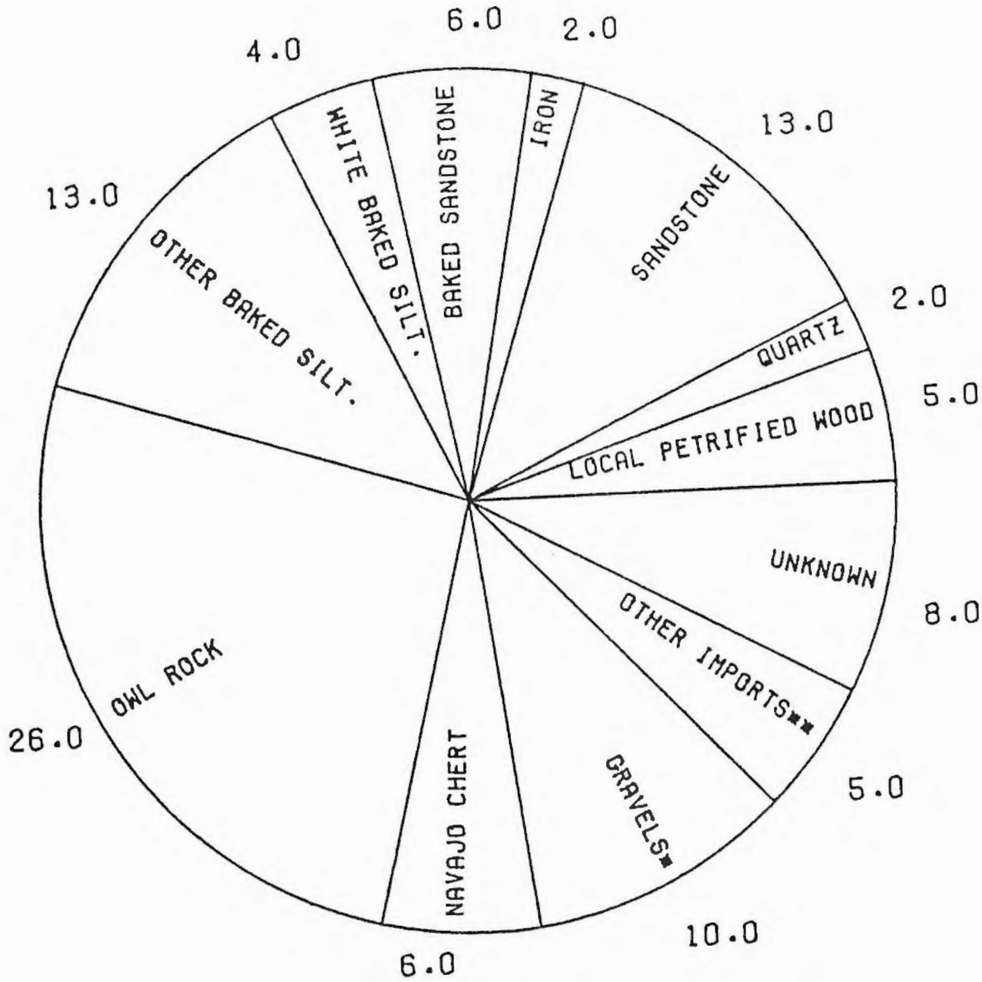
** obsidian; basalt; vitreous petrified wood; pink, Chinle, and fracure-line cherts; creamy opaque

Figure 7. Percents of raw materials at all sites.



* chalcedony; gray, brown, quartzitic, and oolitic cherts

Figure 8. Percents of raw materials at pre-A.D. 800 sites.



* chalcedony; gray, brown, quartzitic, and oolitic cherts

** obsidian; basalt; vitreous petrified wood; pink, Chinle, and fracture-line cherts; creamy opaque

Figure 9. Percents of raw materials at post-A.D. 800 sites.

The last two sites in Cluster I, D:11:445 and D:7:312, are from later and different time periods and are not located in the same drainage. These sites may be located in close proximity to sources of this locally available material, which would explain its predominance there. Although it is not certain in these particular cases, outcrops of baked siltstone produced by proximity to burning in underground coal seams often are exposed by downcutting in washes. Each of these sites lies within the lower reaches of the drainage within which it is located. In both cases, the material that actually makes up the high percentage is gray baked siltstone, not the white variety most often associated with Basketmaker II sites (see Appendix C).

The other raw material groups all have means of less than 2%, and the two materials from the most distant sources, Chinle chert and creamy opaque, are not represented at all in these assemblages. All of the raw materials are represented at sites in Cluster II (Owl Rock, sandstone, baked siltstone, and gravels predominate in that order, each with a mean of greater than 10%). In addition, sites from all time periods (except the undated sites) and all areas are repesented among its membership. It contains the remaining 67 sites, about two-thirds of the total, which indicates that at most of the later sites a wider variety of materials was present than at the Basketmaker II sites where a single material type predominated.

Although the most dramatic break in Ward's coefficient indicates that the two cluster outcome should be selected, it was decided to inspect the three cluster outcome to see where the next division would occur. Site membership in Cluster I remained exactly the same. Cluster

II lost 13 sites; the means for Owl Rock, baked siltstone, and gravels dropped slightly and that for sandstone dropped dramatically. Cluster III is interesting in that it has sites ranging in time from A.D. 850 to A.D. 1100, but all 13 of them are located in Reed Valley. The principal material type that makes up these assemblages is sandstone. Owl Rock materials also are represented in high proportions. Examination of geologic maps (Cooley et al. 1969) indicates no differences in the strata exposed in the areas of the four major drainages; all are sitting on the Wepo Formation, which is composed of siltstone, coal, and gray-yellow sandstone. According to Beaumont and Dixon (1965:A16),

> The percentage of sandstone in the Wepo seems to be the greatest at the northernmost end of Black Mesa near Kayenta Point. There the sandstone makes up about 85 percent of the formation; at other places it constitutes as little as 50 percent of the formation.

However, as Moenkopi Wash is farther north than Reed Valley and sites there have relatively fewer sandstone lithics, it seems that some variation too localized to be reflected on the geologic map may be operating. This cluster of sites may be related to variation in the availability and quality of sandstone across space because its membership crosscuts several time periods. Field inspection of the area would be necessary to investigate this proposition. Alternatively, the differential distribution of sandstone across sites also may be the product of cultural factors, such as different subsistence emphases in different areas, which would have required the use of different tools and/or facilities, and different occupation spans for sites, which would result in a greater build-up of rubble and debris.

Because this strong association of a single raw material type and a drainage was so unusual, it was decided to investigate the Reed Valley sandstone cluster further. It should be recalled that sandstone may be evidence of chipped or ground stone manufacture and/or the shaping of masonry blocks for construction. Chipped stone is present throughout the temporal sequence as, to a lesser extent, is ground stone. However, masonry rooms do not become important until after A.D. 850 and are totally absent at the undated sites. If Reed Valley location were overrepresented at late sites and underrepresented at early sites, it might help explain the predominance of sandstone there. Thus, a two-dimensional chi-square analysis was performed on time period versus drainage to determine if a significant nonrandom association existed between the two. Time periods had to be collapsed for group values to be high enough for the test to be valid (see Table 7). Although

> . . . the actual sampling distribution of chi-square varies only in discrete steps . . . it has proved helpful to approximate the actual discrete chi-square distribution with a continuous curve. . . . The error resulting from this approximation is negligible as long as the expected frequencies remain relatively large. But data in social sciences is often quite scarce, and one must often rely upon relatively small examples. It is thus necessary to adjust the computed chi-square statistic for small samples in order to conform to the theoretical distribution (Thomas 1976:280).

Yates's correction for continuity is used to make the adjustment by subtracting .5 from the absolute value of the difference between the expected and the observed. The equation is

$$\chi_c^2 = \frac{\Sigma(|O_i - E_i| - 0.5)^2}{E_i} .$$

Table 7. Chi-square Results for Location of Sites over Time

Time Period	Moen- kopi Wash	Reed Valley	Red Peak Valley	Dinne- bito Wash	Total
Pre A.D. 800	16*	3	11	1	31
	12%	10%	7%	2%	
A.D. 800-999	11	11	5	1	28
	10%	9%	7%	2%	
A.D. 1000-1149	9	17	7	5	38
	14%	12%	9	3%	
Total	36	31	23	7	97

Uncorrected chi-square = 16.3, df = 6, p = .01.

Chi-square with Yates's correction for continuity = 12.2, df = 6, p > .05.

*16 = observed value
12% = expected value

There is some disagreement in the literature about its application. The rule adopted here follows Thomas (1976:281) after Blalock (1972:286) in using Yates's correction when more than two of the expected values fall below five in a contingency table larger than two by two. It should be noted that the test is no longer valid if more than 20% of the cells have expected values less than five and any expected values less than two (Thomas 1976:298).

The χ^2 value equaled 16.3, a value significant at the .05 level. However, after Yates's correction for continuity was applied, because more than two expected values fell below five, the corrected χ^2 value equaled 12.2, a value not significant at the .05 level. Although not significant at the .05 level, the results clearly are borderline and, as can be seen from Table 7, the figures do indicate a higher than expected number of sites in Reed Valley during the later time periods.

A chi-square test for significance of association was performed next for sites with rooms and their locations with respect to the four drainages (see Table 8). Two variables on the 1975 site survey file, "definite room" and "possible room," were combined to arrive at the number-of-rooms variable used in the test. Wall outlines and presence of sandstone rubble was used to identify these rooms, and "possible room" indicates the presence of at least some sandstone rubble. The results were significant at the .01 level; the major departures from the expected distribution came in the higher than expected number of sites with rooms in Reed Valley and the opposite pattern in Red Peak Valley.

An attempt was made to remove the undated sites from the analysis because none of them have rooms (they are assumed to be too early to

Table 8. Chi-square Results for Location of Sites with Rooms

Rooms	Moen-kopi Wash	Reed Valley	Red Peak Valley	Dinne-bito Wash	Total
Present	22	26	11	4	63
	23%	20%	15%	3%	
Absent	14	5	12	3	34
	13%	11%	8%	2%	
Total	36	31	23	7	97

Chi-square = 11.75, df = 3, p = .01.

have evidence of above-ground masonry construction). However, this test was not valid because more than two expected values fell below five, and one of these was less than two. Instead, mean number of rooms at sites was compared across drainages, and the results indicated that Reed Valley sites have higher than average numbers of rooms (see Table 9).

Significance of association of kivas with drainages also was tested. Kivas on Black Mesa often are built without masonry linings, and their presence would suggest whether all types of buildings were distributed differentially across drainages or if the increased number of masonry rooms in Reed Valley might have been facilitated by availability of construction materials. Number of sites with kivas did not vary significantly across drainages, although Table 10 indicates the same trend as Table 8. Finally, number of sites with ground stone also was tested against drainage for significance of association with the chi-square statistic. This result was significant at the .01 level (see Table 11). Reed Valley sites also have greater per site averages of ground stone than do sites in other drainages (see Table 9).

In sum, although not significant at the .05 level, Reed Valley does tend to have more later sites than do the other drainages. There are significantly more sites with rooms and ground stone in Reed Valley as well. The abundance of sandstone lithics fits readily into this pattern and can be either a result of whatever is causing these other patterns or related directly as the "debitage" from the manufacture of room blocks and/or ground stone. Contributing to the abundance of sandstone at these sites might be natural factors such as the abundance of this material in this particular valley and cultural factors such as

Table 9. Mean Number of Rooms per Site and Mean Number of Pieces of Ground Stone per Site in Each Drainage

Drainage	Rooms		Ground Stone
	All Sites	A.D. 793+	
Moenkopi Wash	.92	1.38	1.89
Reed Valley	1.35	1.45	2.87
Red Peak Valley	.91	.82	.91
Dinnebito Wash	.71	.83	2.57
Grand mean	.97	1.12	2.02

Table 10. Chi-square Results for Location of Sites with Kivas

Kivas	Moen-kopi Wash	Reed Valley	Red Peak Valley	Dinne-bito Wash	Total
Present	15	16	6	3	40
	15%	13%	9%	3%	
Absent	21	15	17	4	57
	21%	18%	14%	4%	
Total	36	31	23	7	97

Chi-square = 6.88, df = 3, p = .08.

Table 11. Chi-square Results for Location of Sites with Ground Stone

Ground Stone	Moen-kopi Wash	Reed Valley	Red Peak Valley	Dinne-bito Wash	Total
Present	22	23	10	5	60
	22%	19%	14%	4%	
Absent	14	8	13	2	37
	14%	12%	9%	3%	
Total	36	31	23	7	97

Chi-square = 11.19, df = 3, p = .01.

increase in the use of masonry rooms and ground stone over time, the long-term occupation of sites in this drainage, and/or differential adaptational emphases that would require the use of sandstone. These factors require further research and are beyond the scope of this study.

The cluster run for local materials alone (see Figure 10) closely approximates that for all materials except that two sites, D:7:500, an undated site, and D:7:312, one of the later sites, were moved from Cluster I (still predominantly baked siltstone [93%]) to Cluster II (a combination cluster dominated by baked siltstone [14%] and sandstone [12%]). D:7:500 has the lowest percentage for baked siltstone of the undated sites (65%); the next lowest is 12% higher. D:7:312 has only 62% of this material, which evidently was not enough, when treating local materials alone, to keep it in that exclusively baked siltstone cluster. The Reed Valley cluster dominated by sandstone was maintained through the three cluster outcome in this local material run, but was combined with sites from other drainages in the two cluster outcome. Two Reed Valley sites not present in this cluster in the all-materials analysis were added to it when the local materials were considered separately.

The nonlocal material cluster analysis differs somewhat from the others (see Figure 11). Two clusters were isolated. The 31 undated and A.D. 793-dated sites remained in Cluster I, which has only low percentages of imports (Owl Rock, 11%; gravels, 9%). However, there are 52 other sites also in Cluster I that range across all of the time periods. It will be easier for purposes of discussion to look at the remaining 24 sites that are in Cluster II, which have an average of 49% Owl Rock and

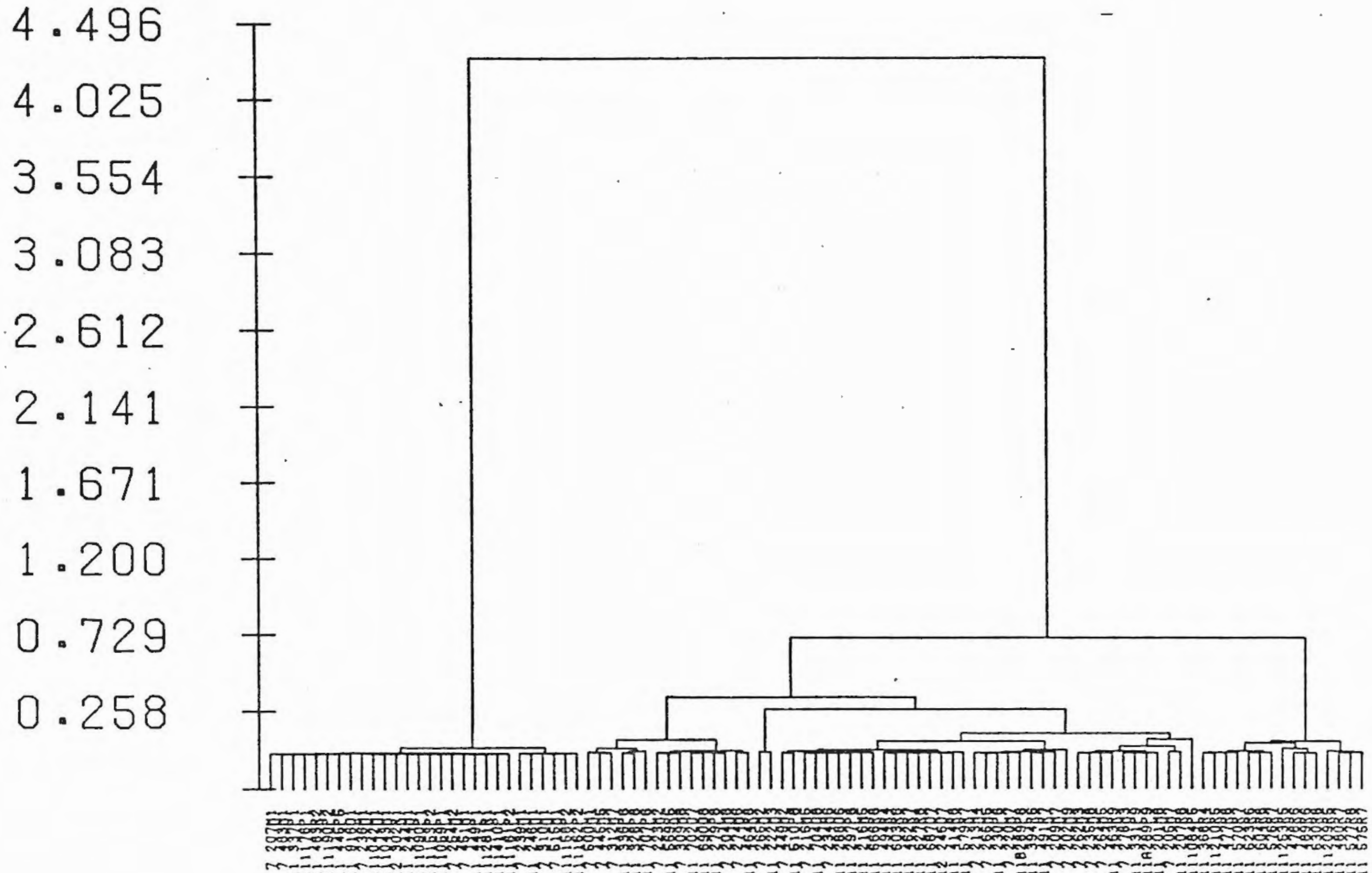


Figure 10. Dendrogram for all sites-local materials.

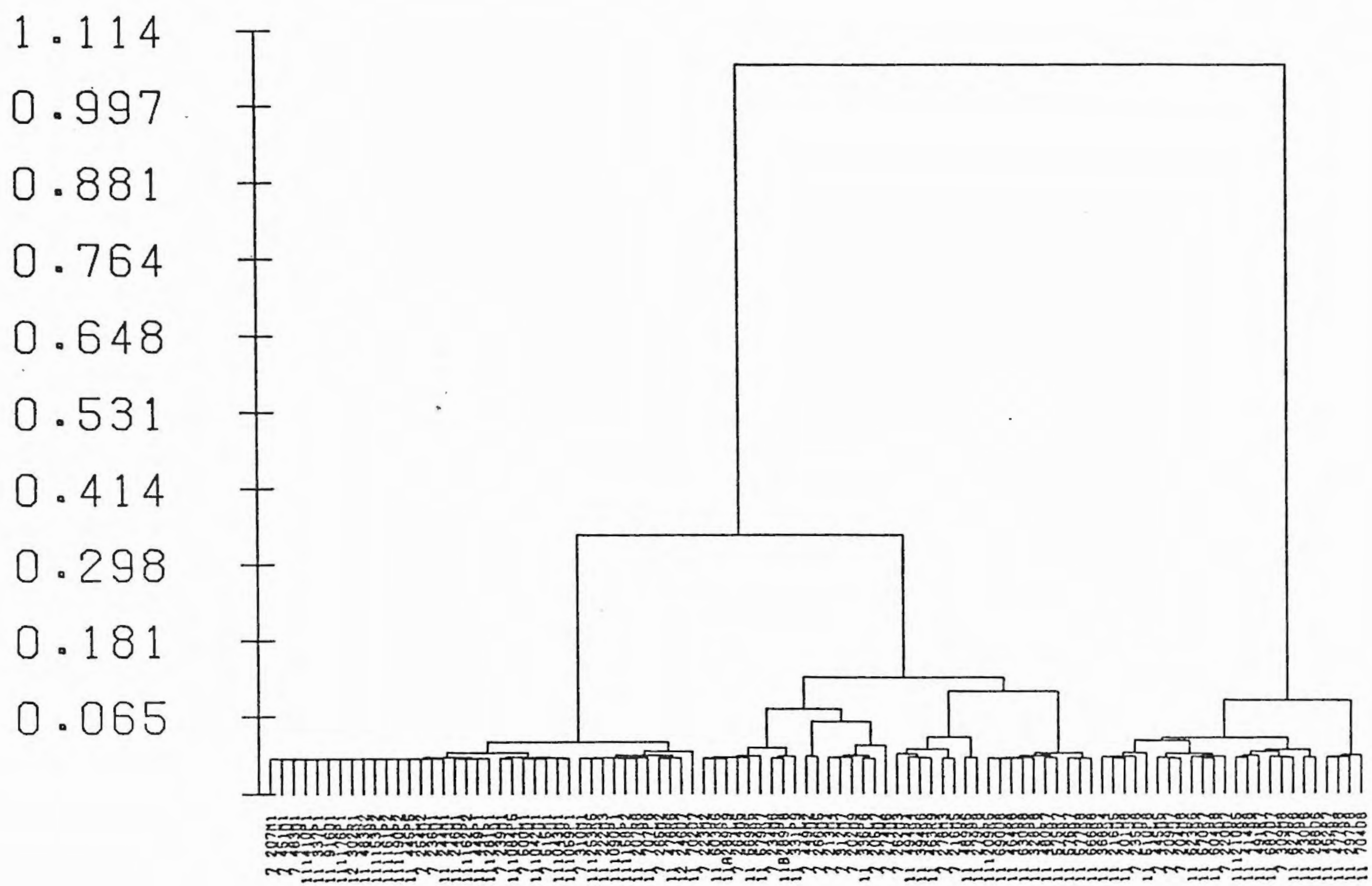


Figure 11. Dendrogram for all sites-nonlocal materials.

between 1 and 6% of each of the other four nonlocal materials. The earliest site in Cluster II dates between A.D. 850 and A.D. 899, and the latest dates between A.D. 1050 and A.D. 1099, so the range of site dates (ca. 1000 B.C. to A.D. 1150) is not represented in its entirety. The early end of the temporal range is conspicuously absent, but the relative disappearance of nonlocal materials at post A.D. 1100 sites is more difficult to explain. All drainages are represented in the sample, with Reed Valley and Dinnebito Wash in slightly greater numbers than their contributions to the total site inventory would suggest, and the opposite true for Moenkopi Wash and Red Peak Valley.

The Reed Valley site cluster dominated by sandstone was not maintained in this cluster run. The formation of three clusters from the two discussed above was done by leaving Cluster II intact and dividing Cluster I in two; one of these has predominantly early sites with very little imported material, and the other has mainly post-Basketmaker sites with moderate amounts of selected imports (Owl Rock, 19%; gravels, 16%). It thus appears that the strong Reed Valley sandstone cluster did not have as much to do with interaction among sites (as would have been indicated by similarities in nonlocal material assemblages) as it did with the other factors discussed earlier.

The most striking pattern that emerges from this cluster series is the fixation on baked siltstone during Basketmaker times and its dramatic decrease during later times. The dramatic discontinuity in assemblage composition is almost certainly accentuated by the near-absence of sites in the study area for several hundred years (see

Chapter II). If more sites were known for the period A.D. 1-800, a more gradual change in raw material types might have become evident.

During later time periods Owl Rock materials became very important, but generally a wider variety of materials was used at post-Basketmaker sites. The importance of Owl Rock seems to crosscut most of the time periods and all of the drainages. Sandstone, however, seems to have been important in Reed Valley throughout most of post-Basketmaker times.

In order to examine the emerging patterns more closely, the cluster series were run individually for each of the nine time periods (see Figures 12-29). Although some of the time periods have numbers of cases too low to make the individual cluster analyses meaningful, it was decided not to lump time periods so as to keep sites in time periods with enough cases as contemporaneous as possible. Only means are presented for time periods with low numbers of sites. The results of the cluster analyses will be presented diachronically rather than synchronically because the study of change in raw material use over time is the issue here. The analyses for local materials alone will be presented with the all-materials runs because their outcomes are similar due to the high frequencies of local materials in the assemblages. Results of cluster analyses for nonlocal materials will be presented subsequently. These results will be supplemented with information on nonlocal materials that were omitted from the analysis for the reasons discussed above.

Cluster Analyses for All Materials and Local Materials Over Time

The analysis for all materials at undated sites (n = 21) resulted in two clusters (see Figure 12). Cluster I has 17 sites with a mean of 95% for baked siltstone and a mean of no more than 1% of any other material. Local petrified wood, quartz, Chinle chert, and creamy opaque are absent from these sites. Baked siltstone is such a soft material that the major types of materials used in hard hammer flaking (local petrified wood and the quartzes) may not have been needed in its manufacture. Although bone or antler flakers rarely are found, it is probable that these were used more often than stone hammers in the production of baked siltstone tools. This material often occurs as naturally fractured "flakes" and so only the later stages of manufacture, during which antler batons often are used, would have been necessary.

Cluster II includes four sites which have a mean of 77% for baked siltstone and the remainder made up of 1 to 5% of the rest of the materials except sandstone, Chinle chert, and creamy opaque, of which there are none. One interesting attribute shared by these sites is their location—all are located right at Moenkopi Wash. Thus, the earliest sites have very little of any materials available off the mesa; in fact, they have very little of any materials other than baked siltstone. The few sites with nonlocal materials are located in Moenkopi Wash.

It should be noted that 12 of 21 (57%) of the undated sites are located in Moenkopi Wash, but this does not account for 100% of the

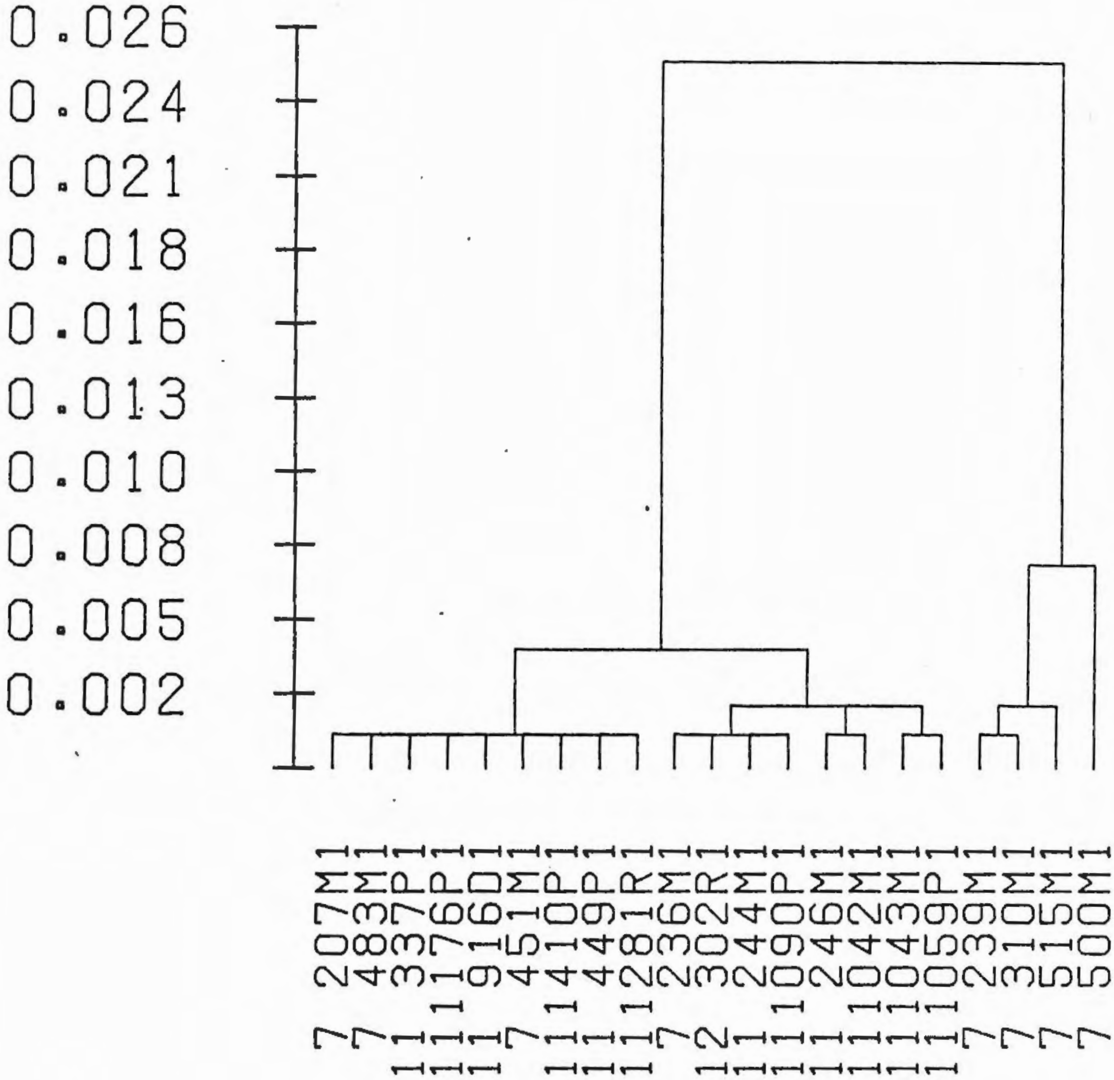


Figure 12. Dendrogram for undated sites-all materials.

sites with nonlocal materials located there. This wash has been hypothesized as the best access to the valley below Black Mesa, and thus the most obvious trade route if one existed (Borger 1979). These results seem to support an earlier beginning for use of this trade route than was implied in the 1979 study, which did not have information about the dated Basketmaker II sites. The results of the local material analysis are similar to the previous one (means remained essentially the same), except that another Moenkopi Wash site, D:11:246, was added to the second cluster (see Figure 13).

The cluster analysis was performed next for the 10 sites in the A.D. 793 time grouping. These sites were assigned this date based on the ceramic analysis performed by Hantman and Plog (1978). It is the base date for their regression equation and, because these sites have insufficient ceramics to be dated, they were left with the base figure. It is believed there actually is a long time span represented in this group because of results of excavation that enabled successful dating of several of these sites (D:11:1161 and D:11:1162) to the Basketmaker II time period. Thus, cluster divisions within this time period may be based on temporal change in addition to other factors.

Two clusters were isolated (see Figure 14). The first cluster has three sites, all of which are located in the Moenkopi Wash area. In keeping with earlier results it is the cluster with more nonlocal materials (51% nonlocal cherts). These sites also have a greater mean percentage of hammerstone materials, the toughness of which is necessary for chert reduction (30% combined hammerstone materials). Baked siltstone drops to an average 11% in this cluster. The seven sites in

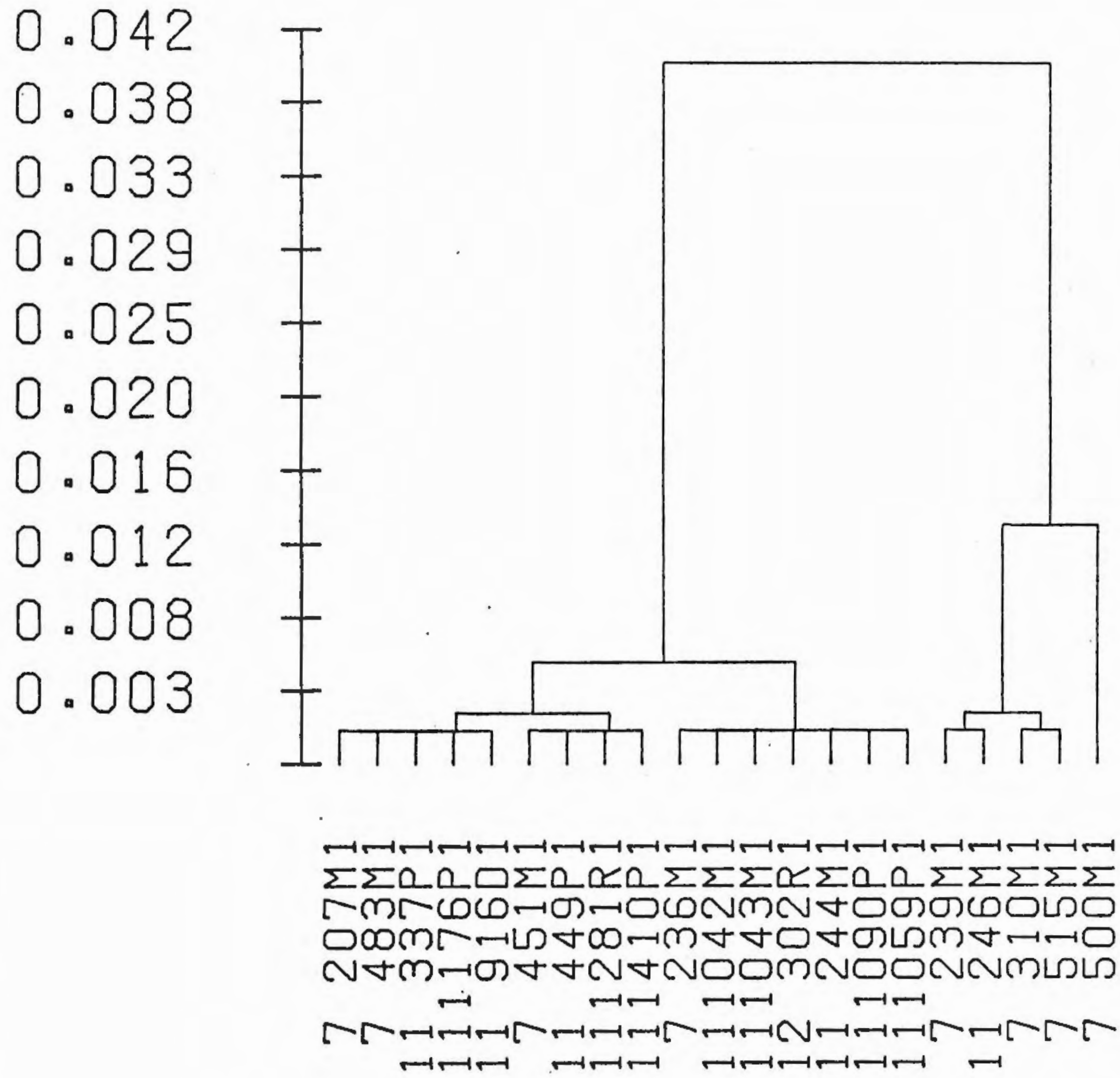


Figure 13. Dendrogram for undated sites-local materials.

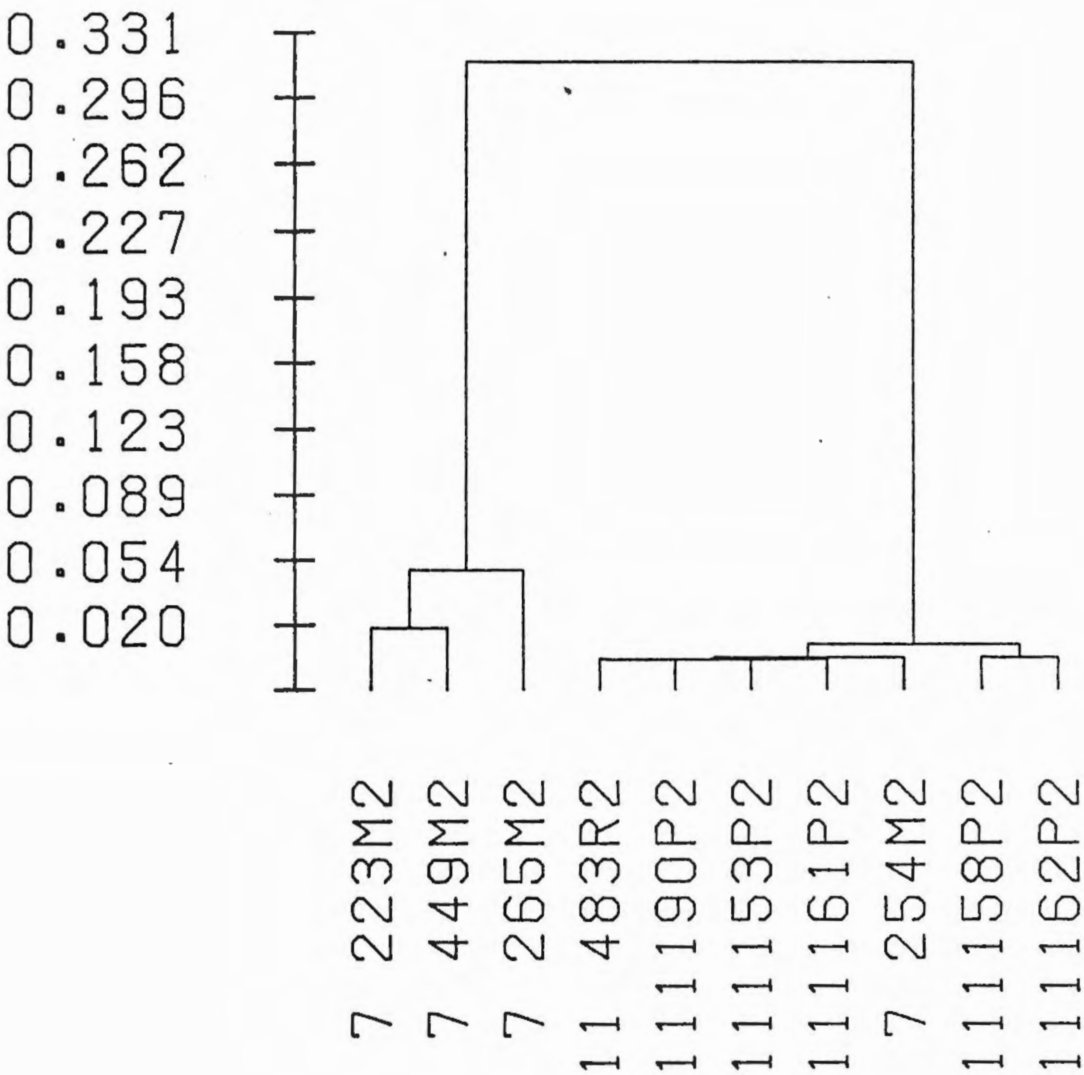


Figure 14. Dendrogram for A.D. 793 sites-all materials.

Cluster II resemble the Basketmaker II assemblages discussed earlier. They have a mean of 91% for baked siltstone and only a combined 2% of imported cherts. The low percentage of the assemblage contributed by hammerstone materials (3%) probably is related to the lack of harder chipping materials (cherts).

Sites in Cluster II are located in three drainages: five sites are from Red Peak Valley, and one each is from Moenkopi Wash and Reed Valley. Although the dating for these sites is vague and probably spans a long range of time, it is interesting that the spatial pattern noted earlier whereby Moenkopi Wash sites are associated with greater amounts of nonlocal materials than sites in other areas still holds true. The analysis for local materials only at A.D. 793-dated sites exhibited exactly the same outcome as that for all materials for that period (see Figure 15).

It will be possible to talk only about trends in means for the next two time periods (A.D. 800-849 and A.D. 850-899) because there are too few cases (n = 3 for each) to generate clusters. During the A.D. 800-849 time period, baked siltstone exhibits the lowest mean so far, only 7%. Baked sandstone is high (mean = 36%) and imported cherts have increased (means combined of Navajo, Owl Rock, and chert gravels = 47%). Some of the more distant imports also appear. Chinle chert and basalt each has a mean of 1%. All three of these sites are located in the Moenkopi Wash area. One of the sites (D:11:222) has an unusually high percentage of baked sandstone (80%) so the mean for this material at the three sites really may not be representative; the mean without that figure is only 15%.

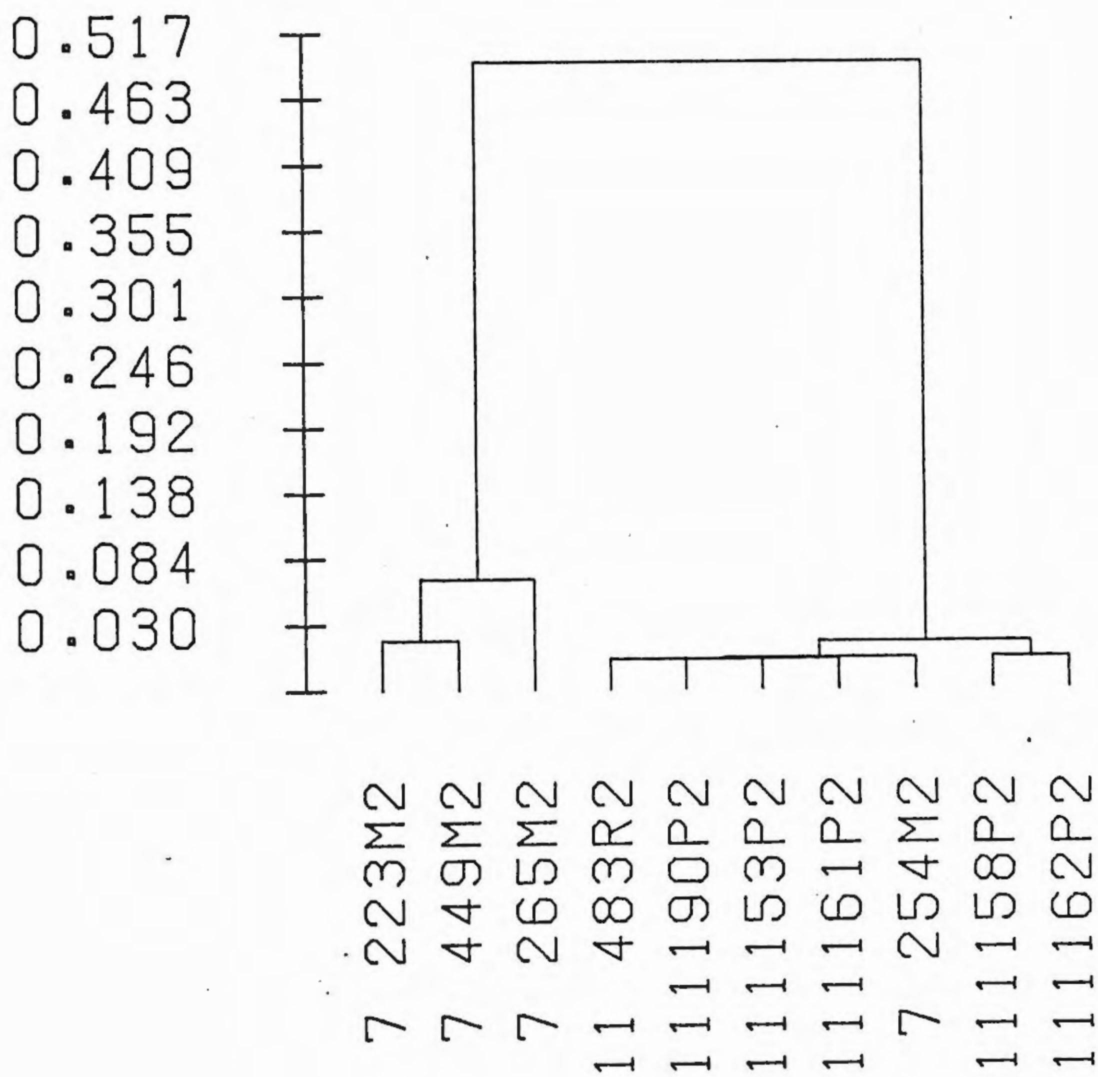


Figure 15. Dendrogram for A.D. 793 sites-local materials.

At the A.D. 850-899 sites, means are similar to those of the preceding phase. Baked siltstone is down to 3%. Imported cherts comprise 44% of the assemblages with 3% of that figure contributed by the more distant materials. These materials, creamy opaque from the Four Corners area and Chinle chert from the opposite direction in the Cameron area, are at the two Reed Valley sites, but one material is at one site and the other material is at the other site. The sample sizes are extremely low so this may be the result of sampling error, but if it is real it supports the model proposed earlier. Thirteen percent of the assemblages are hammerstone materials. Sandstone, which up to this point virtually has been absent, is an average 17% of these assemblages. This appears to be the early end of the Reed Valley phenomenon mentioned earlier, as the single Moenkopi Wash site has no sandstone. In general, during these two time periods the percentage of baked siltstone diminished almost to zero, imported cherts increased, and distantly procured materials are introduced but not shared.

The 11 sites dating from A.D. 900 to A.D. 949 were separated into three clusters using Ward's method (see Figure 16). Cluster I, with six sites, has low percentages of all the materials. The two dominant material groups are Owl Rock and gravels. Combined imported cherts here comprise a mean of 57% of the assemblages. Three of the four sites in this time period with the most distantly obtained materials, creamy opaque and Chinle chert, are in Cluster I. Again, they are at different sites and still in very low frequencies. The Moenkopi Wash pattern noted earlier is still present; four of the six

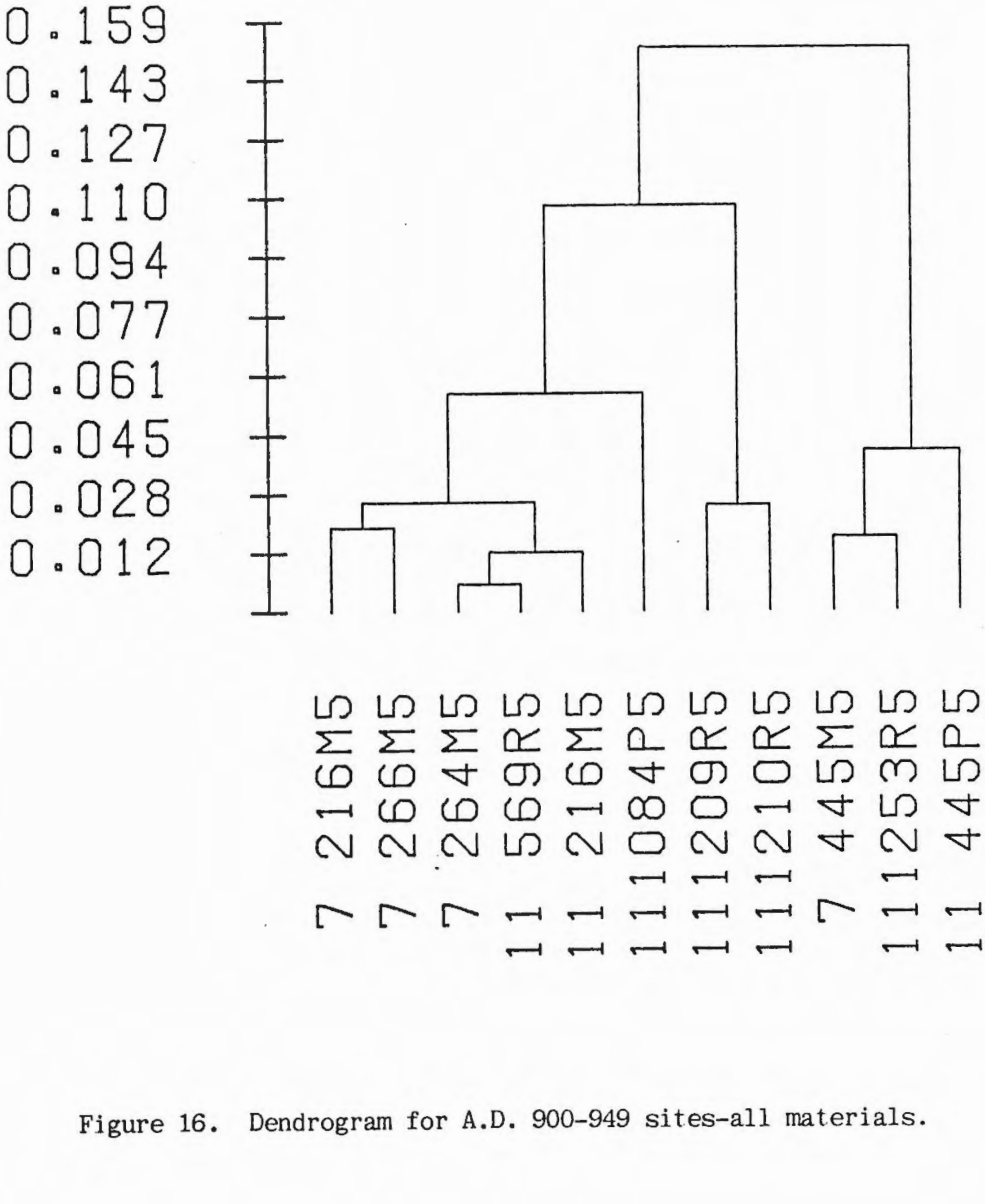


Figure 16. Dendrogram for A.D. 900-949 sites-all materials.

sites in this cluster are from Moenkopi Wash and four of the five Moenkopi Wash sites in this time period are in Cluster I.

Cluster II is a sandstone-dominated cluster (56%), composed of two Reed Valley sites. Owl Rock materials also are important in this cluster (34%). With the exception of sandstone, there are no locally available materials at these two sites.

Cluster III sites have a predominance of baked siltstone (67%) and lesser amounts of Owl Rock (15%) and sandstone (11%). They have almost nothing else with the exception at D:11:1253 of a single obsidian artifact with its source at Superior, Arizona, 325 miles to the southeast of Black Mesa (Lee Sappington, personal communication). The local materials analysis for A.D. 900-949 divided the sites into the same three clusters as the all-materials analysis with the same means for both (see Figure 17).

Three clusters were formed for the 11 A.D. 950-999 sites also (see Figure 18). Cluster I has the same dominant materials as the last time period, Owl Rock and gravels (61% combined chert imports), but this time all the drainages are represented in its membership (Reed Valley, 2; Red Peak Valley, 1; Moenkopi Wash, 1; and Dinnebito Wash, 1). Cluster II has mainly baked siltstone (37%) and approximately 30% cherts. Chinle chert and creamy opaque are still in different assemblages during this period. One site in Moenkopi Wash (D:7:274) has 24% creamy opaque material, which is the highest percentage at any site for either of these imports for all time. Cluster III also has about 30% combined cherts but its dominant material is sandstone (43%) and its three sites are located in Reed Valley.

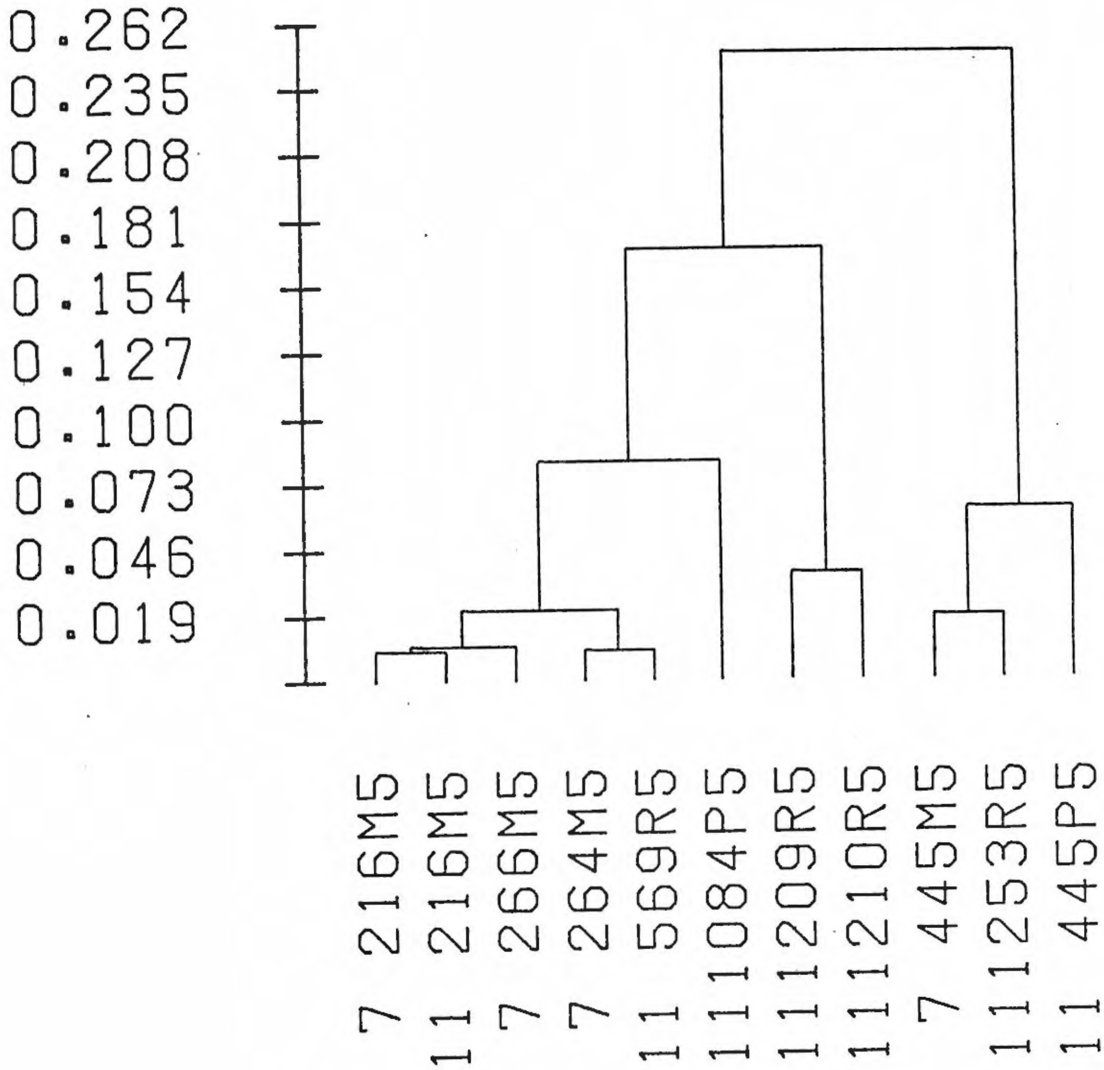


Figure 17. Dendrogram for A.D. 900-949 sites-local materials.

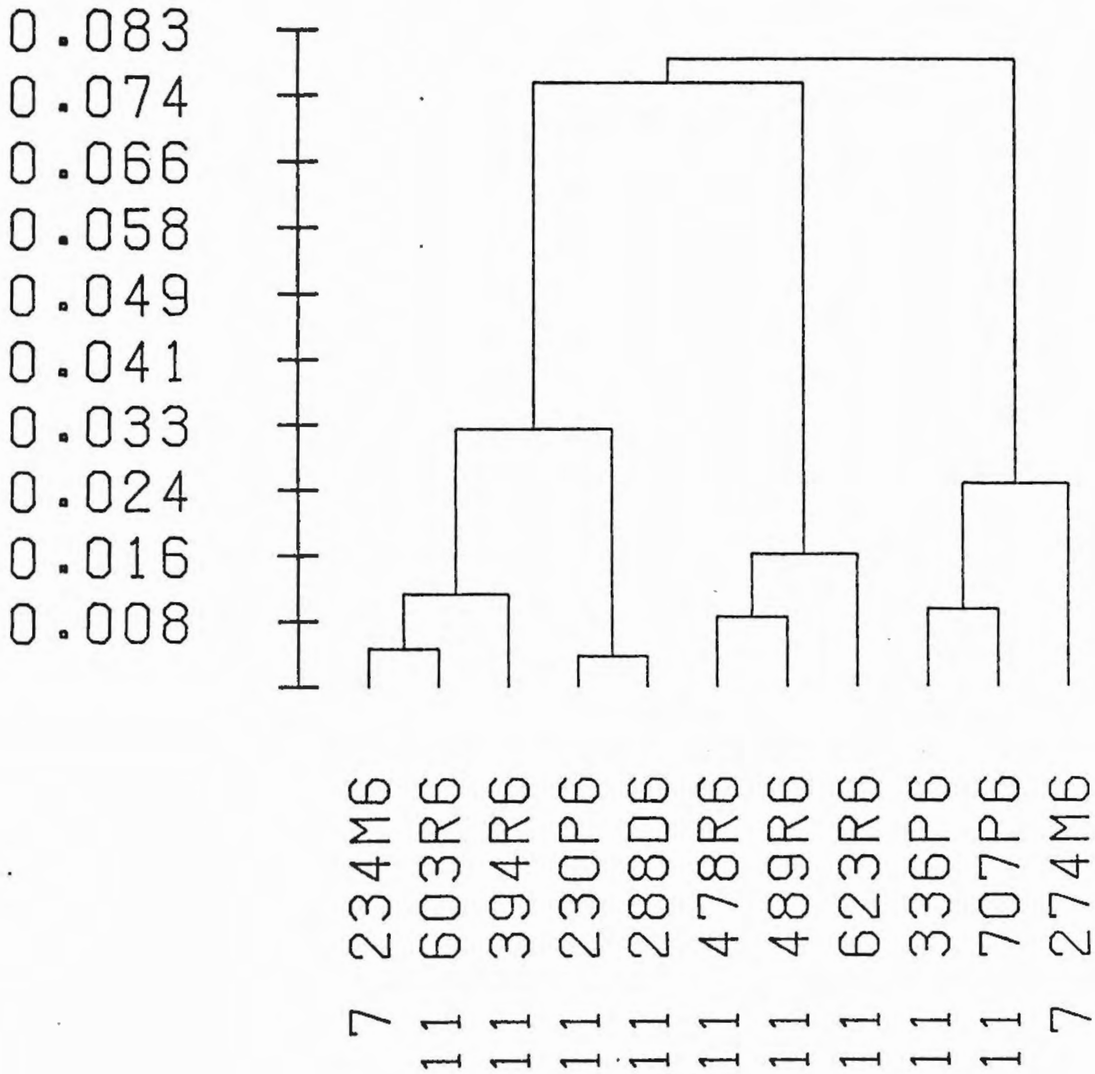


Figure 18. Dendrogram for A.D. 950-999 sites-all materials.

The local materials analysis for the A.D. 950-999 time period changed somewhat from the all-materials procedure (see Figure 19). A Moenkopi Wash site was added to the already diverse membership of Cluster I. Sites in this cluster have no more than 9% of any local raw material type. Cluster II was left with only two sites, both located in Red Peak Valley. These sites have high percentages of baked siltstone (43%), mainly the colored varieties, and lesser amounts of other local materials. Red Peak Valley, so named for its hills of red clinker (technically, baked siltstone), is a likely area to find an abundance of this material on sites. Cluster III is composed of three sites and is essentially a Reed Valley sandstone cluster.

Again, three clusters were defined for the 14 A.D. 1000-1049 sites (see Figure 20). Cluster III is a Reed Valley sandstone cluster with four sites (48% sandstone, 24% Owl Rock). Cluster I has five sites from all drainages except Red Peak Valley, which has no sites representing it during this period. Raw materials in these assemblages are mainly baked siltstone (26%), gravels (17%), and Owl Rock (13%). The remainder of these assemblages is divided among all the other raw materials. Cluster II has five sites, also crosscutting all drainages except Red Peak Valley, but in this cluster Owl Rock (47%) predominates, with local petrified wood (13%) next in order. A single obsidian artifact was found at D:11:687, a Dinnebito Wash site, and the obsidian source was pinpointed at Government Mountain, near Flagstaff (Lee Sappington, personal communication). Import cherts constitute 67% of the total assemblage, whereas in Cluster I they are 38% of the total and in Cluster III they are 31% of the total. Interestingly, this time

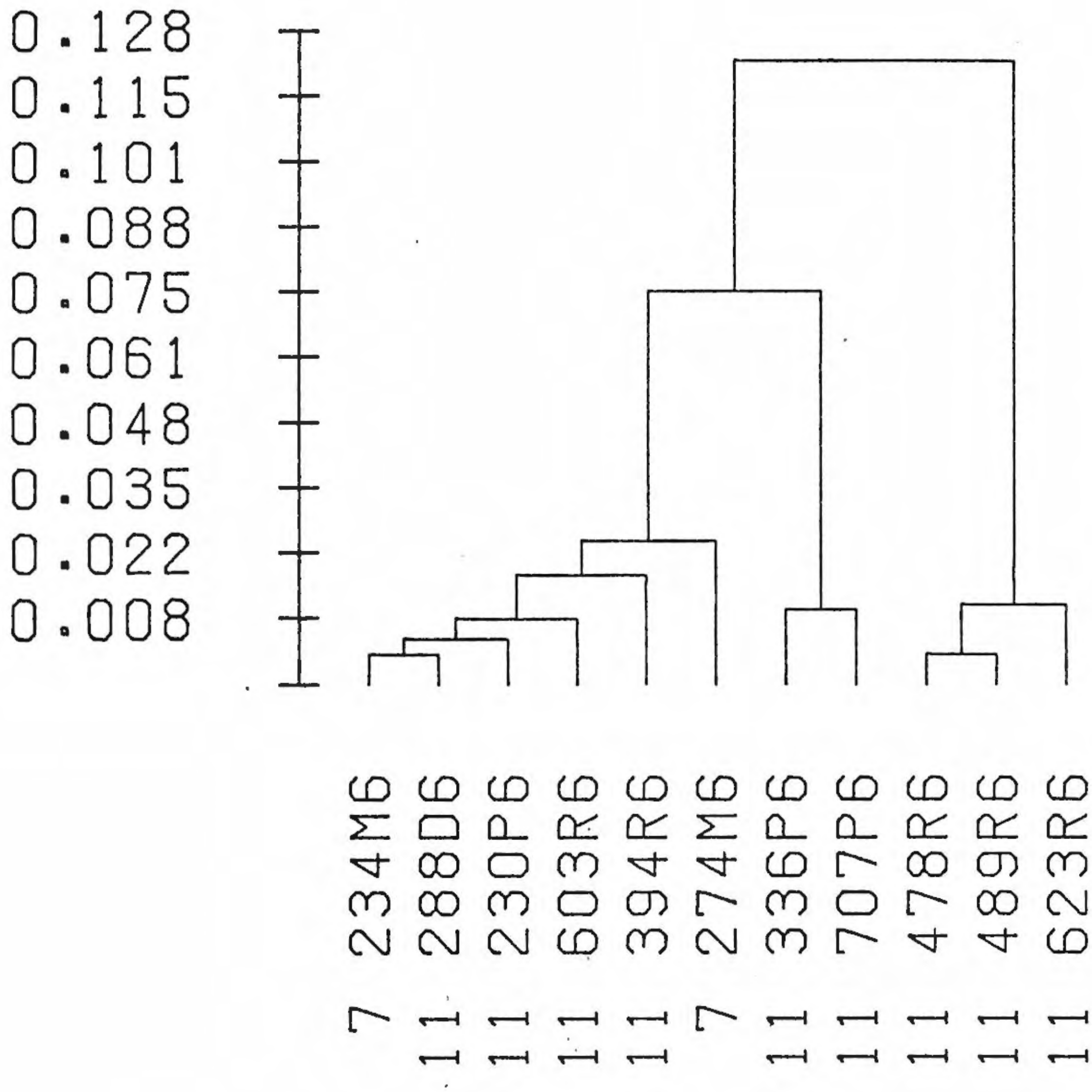


Figure 19. Dendrogram for A.D. 950-999 sites-local materials.

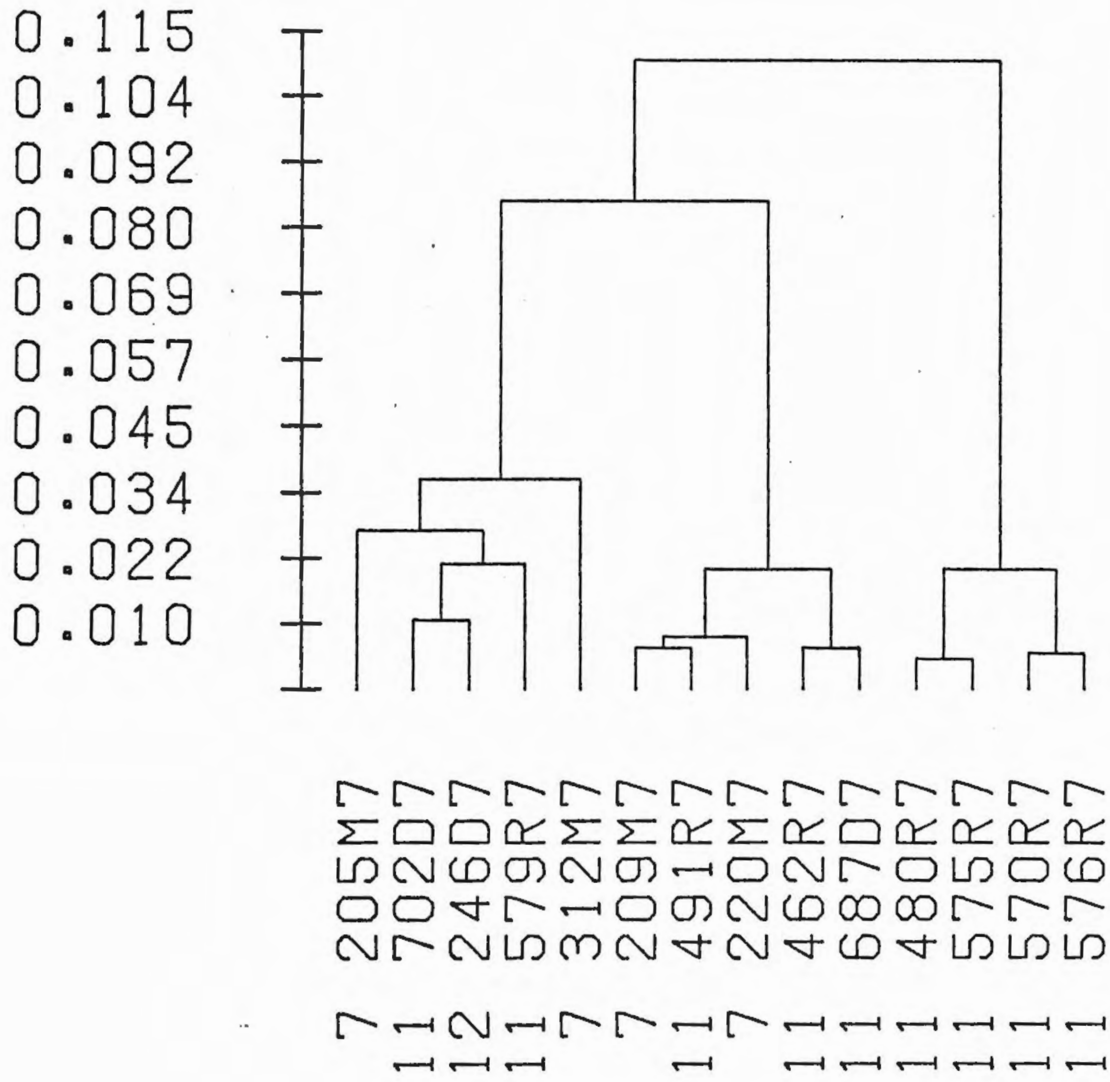


Figure 20. Dendrogram for A.D. 1000-1049 sites-all materials.

period is the first time Chinle chert and creamy opaque are found in assemblages together. This occurs at three sites, two of which are in Reed Valley and one in Dinnebito Wash. If inhabitants of Moenkopi Wash sites were the first to have access (whether through direct means or exchange) to raw materials with distant sources, it would not be surprising to have the first combinations of these materials at sites away from Moenkopi Wash. If people at these other sites did not have access to these fine-grained materials, it is likely that they would trade for them with other people on the mesa and that the materials would wind up in assemblages together. So, by the preceding time period trade in chipped stone raw materials seems to have spread to the rest of the mesa from its beginnings in Moenkopi Wash. By this period trading in different types of distantly obtained materials also appears to have been shared.

The analysis for local materials at A.D. 1000-1049 sites collapsed the first two clusters into one and retained the Reed Valley sandstone cluster (see Figure 21). Cluster I sites have a mean of less than 40% of total local materials, and Cluster II sites have, on the average, greater than 65% local materials (48% of this is sandstone).

The 20 sites from time period A.D. 1050-1099 were divided into three clusters (see Figure 22). The first cluster has a predominance of Owl Rock material (52%); no other material comprises more than 9% of the total. Imported cherts make up 68% of the total, and in Cluster II they form 31% of the total. Cluster II assemblages are more evenly divided among Owl Rock (23%), baked siltstone (28%), and sandstone (9%). Sites in the first two clusters again are fairly evenly divided among all

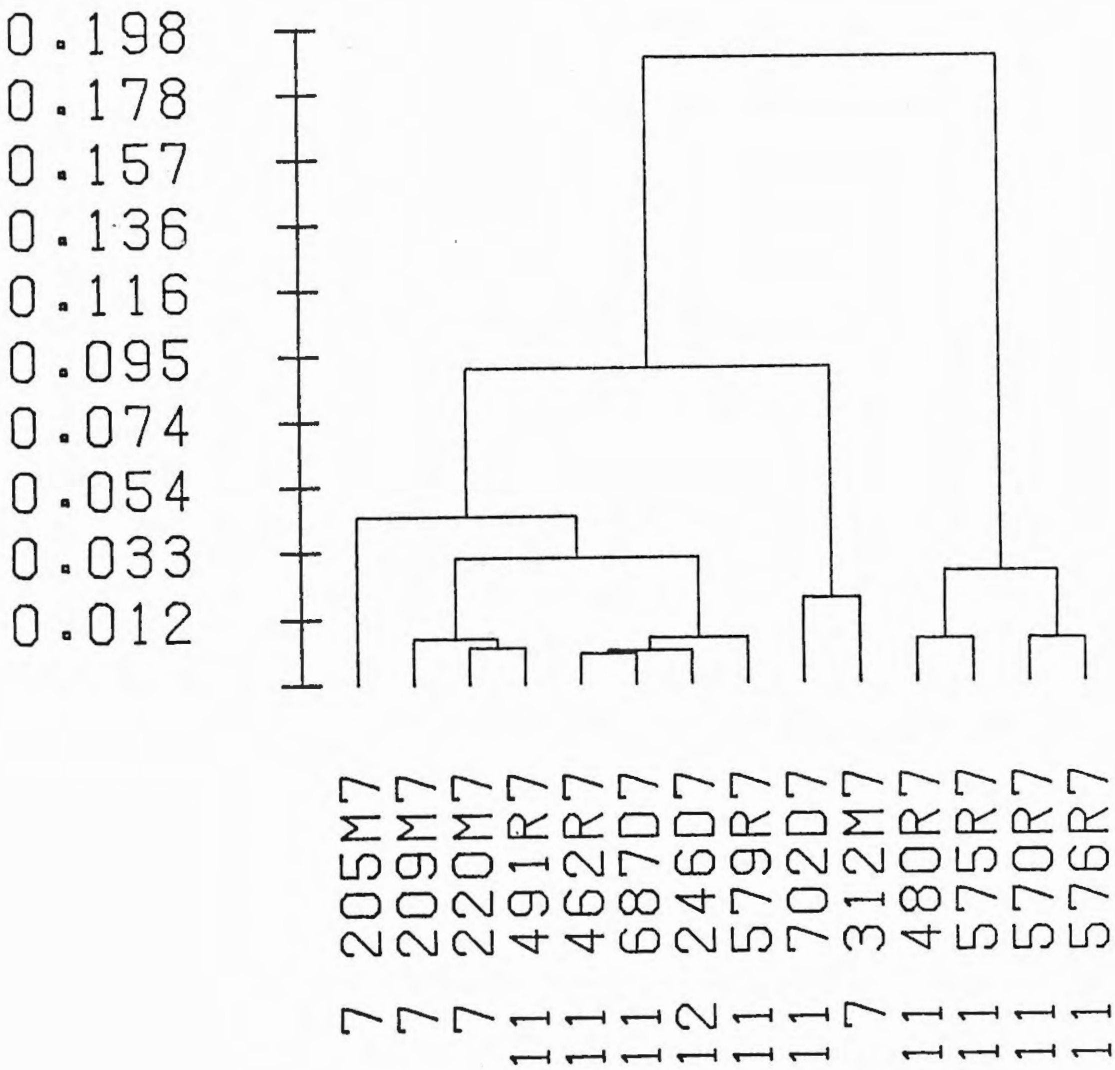


Figure 21. Dendrogram for A.D. 1000-1049 sites-local materials.

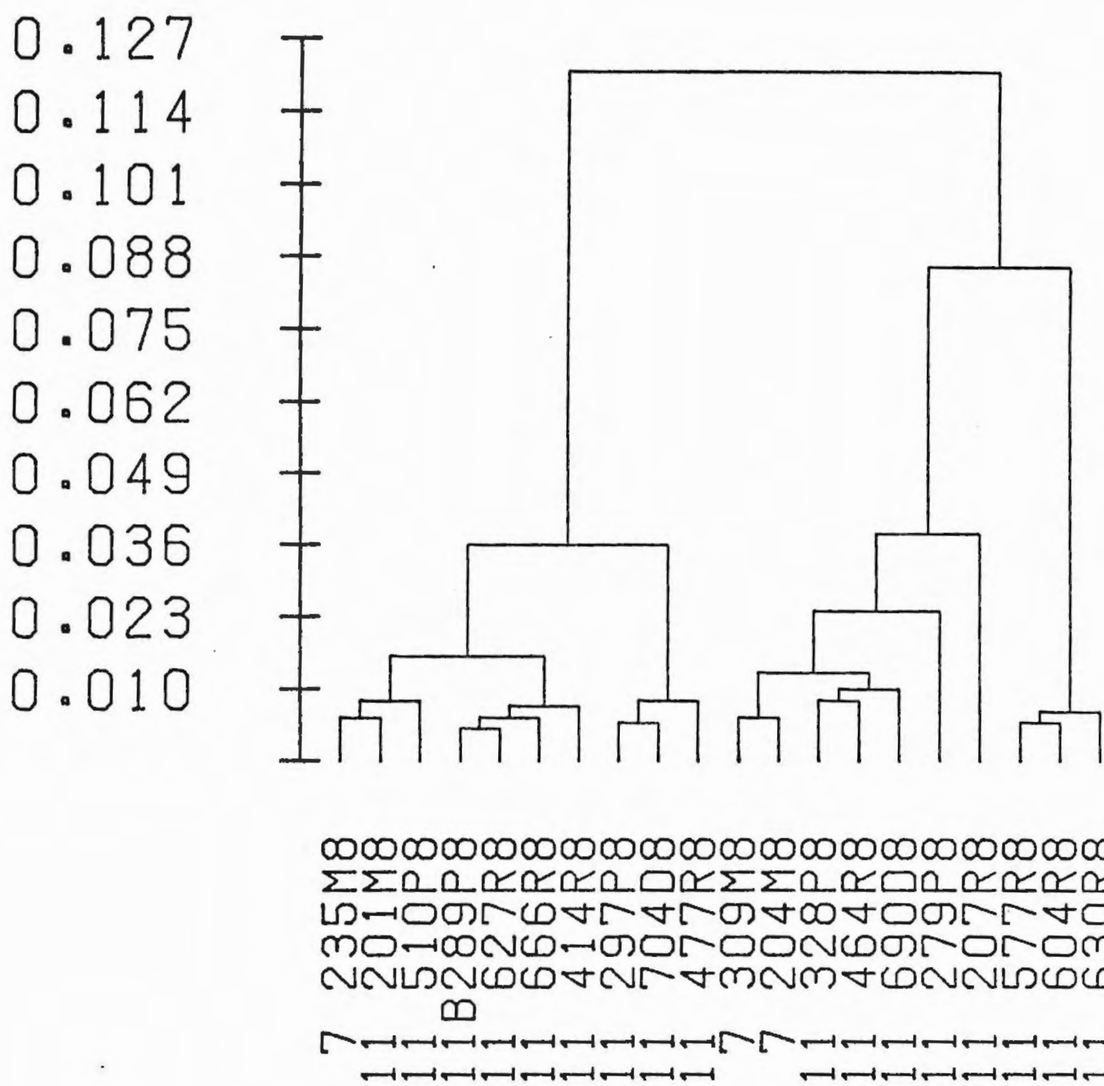


Figure 22. Dendrogram for A.D. 1050-1099 sites-all materials.

drainages. The third, however, is the sandstone-dominated cluster particular to Reed Valley (50%), but it has only three of the nine Reed Valley sites from this time period. Owl Rock again is secondary in this cluster (29%).

The Reed Valley sandstone cluster is Cluster II in the local materials only analysis (see Figure 23). The remaining 17 sites are in Cluster I, which has a mean of 34% for total local materials in contast to the 63% average in Cluster II.

The final time period, A.D. 1100-1149, has only four sites, so only the means are examined. These assemblages are divided among gravels (20%), Owl Rock (20%), local petrified wood (14%), baked sandstone (14%), baked siltstone (11%), and Navajo chert (9%). There is no creamy opaque at any of these sites. Perhaps most interesting is that none of these sites has the very high percentages of Owl Rock seen earlier, and the compensation for this appears to be the use of more locally available materials.

Cluster Analyses for Nonlocal Raw Materials over Time

In the following discussion the term import will be used to indicate any raw material not available in outcrop on Black Mesa. The phrase rare import will indicate raw materials available only at great distances from the mesa and/or that appear in very low frequencies in the assemblages. Owl Rock material, Navajo chert, and gravels are the imports that are *not* considered rare. The rare imports include vitreous petrified wood (possibly from the Petrified Forest National Monument area to the southeast), pink chert (from east of Kayenta and northeast

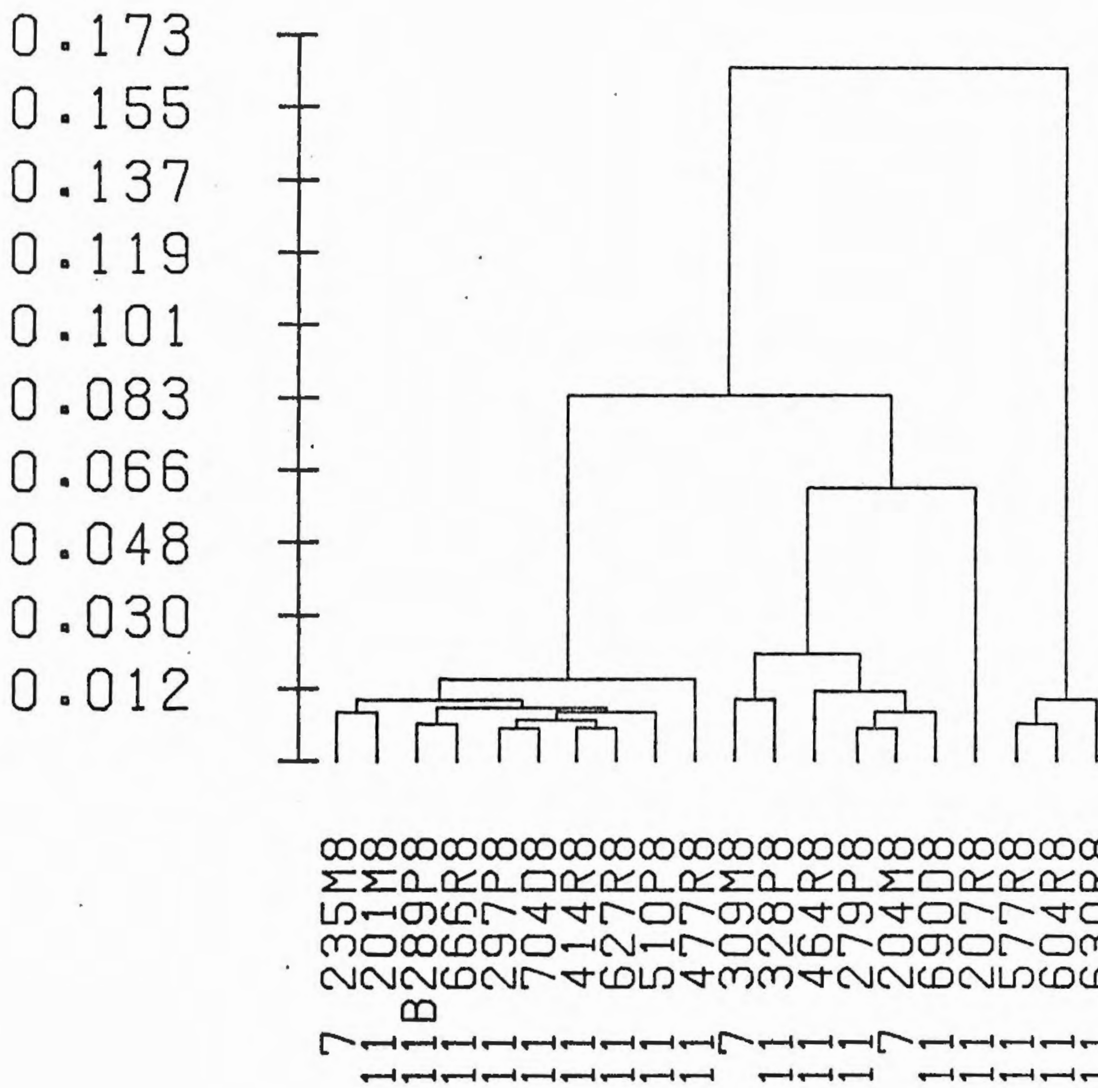


Figure 23. Dendrogram for A.D. 1050-1099 sites-local materials.

of Black Mesa), fracture-line chert (which occurs in the Dakota Sandstone and may have a local source, but has never been seen in usable form locally and has been found in usable form in the Mesa Verde area to the northeast), obsidian (from several sources when considering all Black Mesa sites, but almost exclusively from Government Mountain near Flagstaff to the southwest for sites in this sample), basalt (from unknown source or sources but possibly from the same volcanic field as the obsidian), creamy opaque material (from the Four Corners area to the northeast), and Chinle chert (from the Cameron area to the southwest). In many cases only a single artifact signals the presence of a material at a site, but sample sizes are not crucial since even a single artifact in a sample indicates interaction through the sharing of raw materials. The only rare imports used in the cluster analysis due to low sample sizes are Chinle chert and creamy opaque; thus, in the context of the cluster analysis results, rare imports refers to these two materials only.

The nonlocal material cluster analysis for undated sites differs somewhat from the other analyses for that time period (see Figure 24). Fifteen of the 21 sites have 1% or less of each of the imports, whereas six sites from a second cluster have up to 6% of each import type. Five of these six sites are located in the Moenkopi Wash area.

The nonlocal material cluster analysis for the A.D. 793 sites is similar to the other analyses for that time period in that two clusters were generated (see Figure 25). However, the first cluster lost one of the Moenkopi Wash sites. As a result, the means for Navajo chert, Owl Rock, and gravels all increased. The eight sites in the second cluster

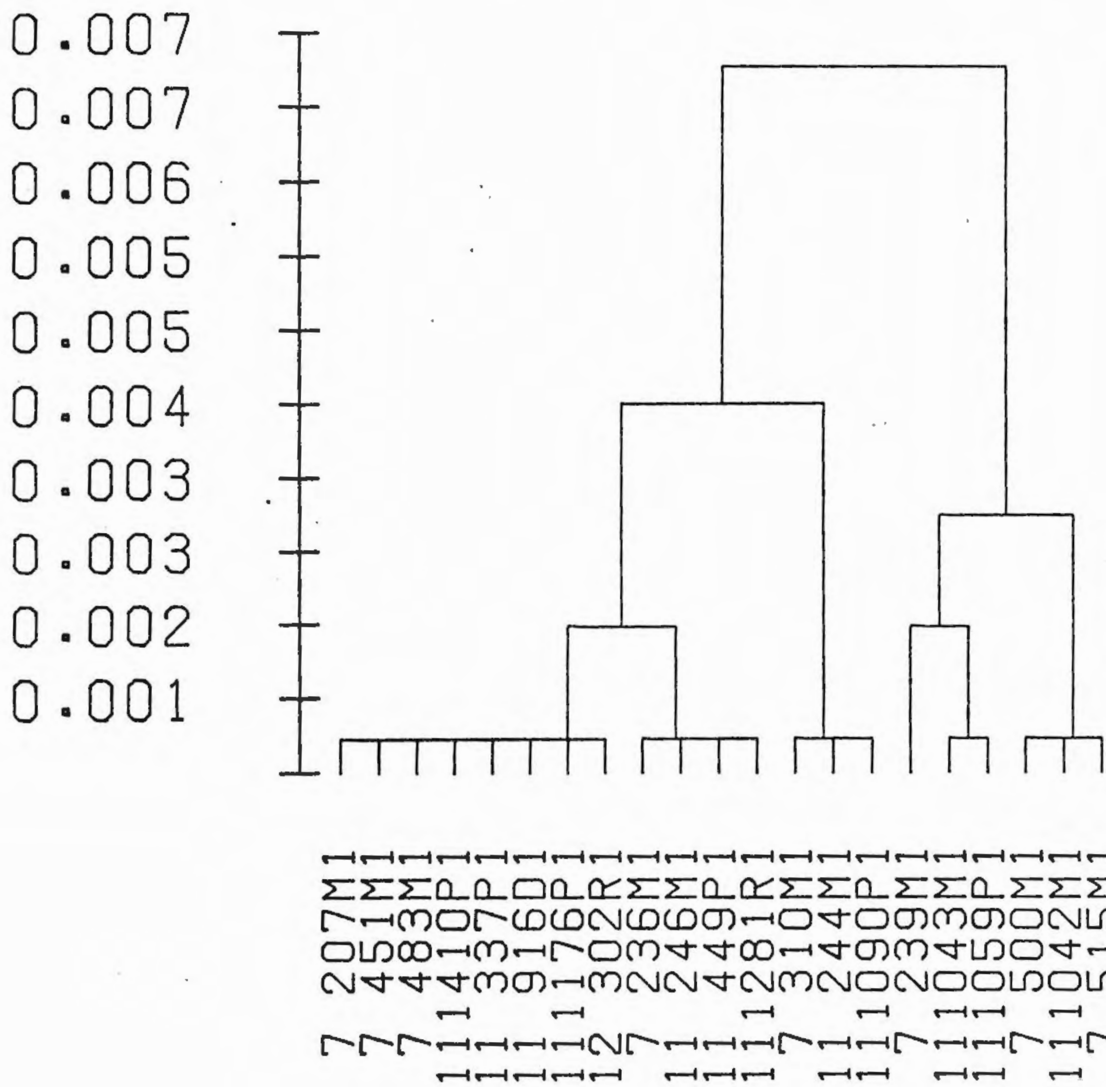


Figure 24. Dendrogram for undated sites-nonlocal materials.

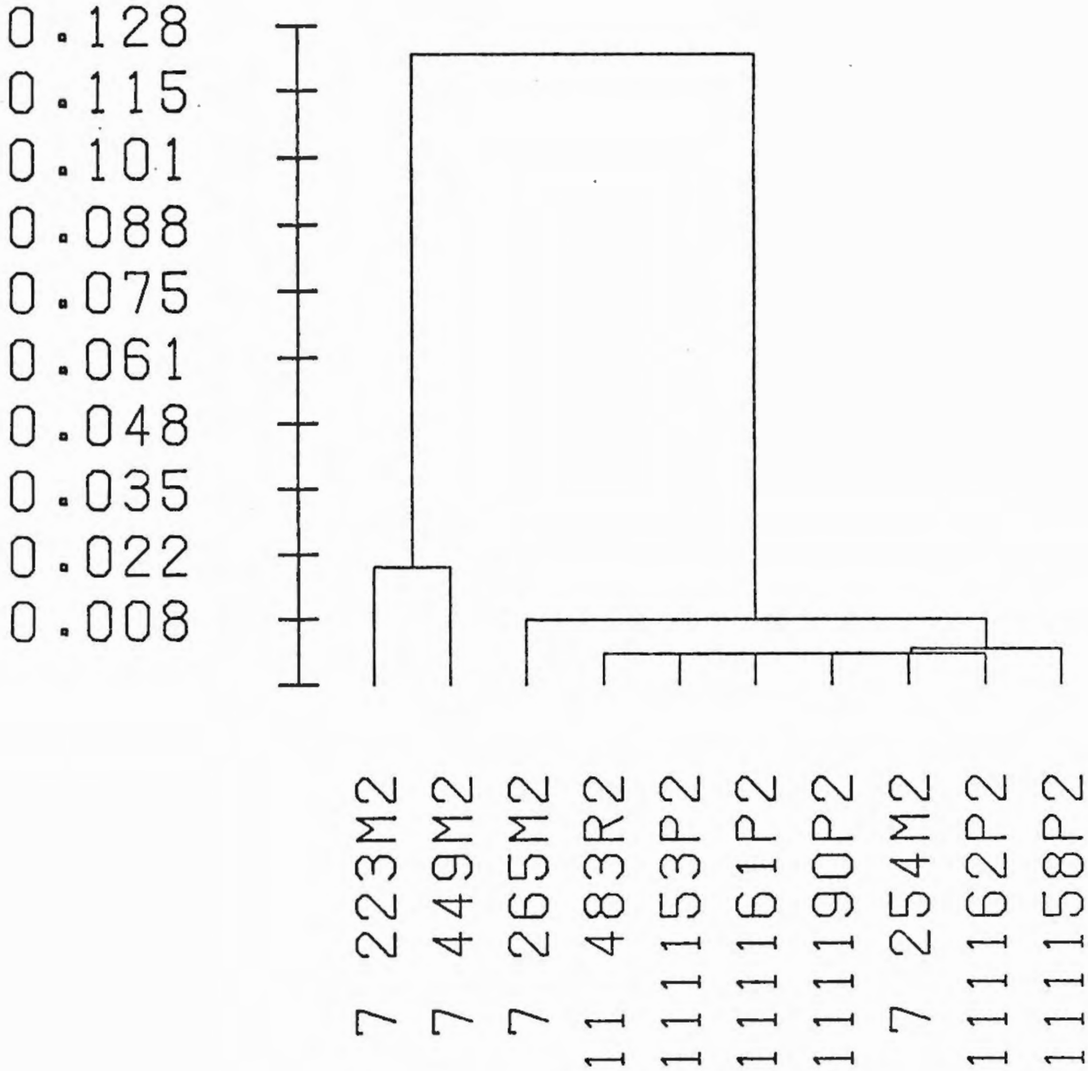


Figure 25. Dendrogram for A.D. 793 sites-nonlocal materials.

have no more than 2%, on the average, of any nonlocal material. Three sites dating to A.D. 793 have rare imports. One has pink chert and the other two have fracture-line chert. The latter two sites, D:7:265 and D:11:1162, are located in Moenkopi Wash and Red Peak Valley, respectively. Sharing of raw materials at this early stage is contrary to the proposed model for inreasing interaction over time. However, of the materials listed above, fracture-line chert is unusual in that it may have been available locally. In summary, at this time, amounts of imported materials are still very low, the most distantly obtained imports have not even entered the picture yet, and the few sites that have imports have fairly high percentages of them and generally are located in Moenkopi Wash.

Four rare imports are at two of the three sites dating to A.D. 800-849, but the two sites do not have the same materials. One site, D:7:262, has three of the materials (basalt, petrified wood, and Chinle chert); D:11:222 has fracture-line chert. Both sites are located in Moenkopi Wash. Each of the three sites dating from A.D. 850-899 has a rare import, but again all are different. D:7:213 has a fracture-line chert, D:11:494 has Chinle chert, and D:11:368 has creamy opaque material. By A.D. 899 imports from the entire range of source areas are found at sites on the mesa. Only two sites within any of the four time periods (n = 37 sites) mentioned thus far share the same import, fracture-line chert. Each of the other seven sites with rare imports is the only one during its time period to have that material. Also, until A.D. 899 only one site, D:7:262, in Moenkopi Wash, has more than one rare import. Thus, it appears that up to this point possession of rare imports was not widespread (they are at only nine of 37 sites and all except one Red Peak Valley site were located in Moenkopi Wash), and sharing of the materials between roughly contemporaneous sites was almost nonexistent.

The nonlocal materials cluster analysis for the A.D. 900-949 sites recombined a number of the sites and made trends observed for the nonlocal materials in the all-materials analysis more distinct (see Figure 26). Five of the 11 sites have imports, and five raw material types are represented. However, two of these types, pink chert and Chinle chert, are each located at two or more sites. Two of the sites that have Chinle chert, D:11:1210 and D:11:569, are in close proximity to one another in Reed Valley. The third, D:7:264, is at some distance away in Moenkopi Wash. D:7:264 also has two other imports, fracture-line chert and pink chert; the latter is also at D:7:216, a site nearby in the Moenkopi Wash area. Thus, there is a greater trend toward the possession and sharing of raw materials, or information about procuring them, that connects the Reed Valley and Moenkopi Wash areas at this time.

Although Moenkopi Wash sites make up 52% of the 48 sites that date prior to A.D. 950, they make up 71% of the sites with rare imports. In addition, up to A.D. 950 only three sites have more than one rare import. One (D:11:569) is from Reed Valley and it has basalt and Chinle chert; the other two, both from Moenkopi Wash, have three rare imports each. D:7:262 has basalt, Chinle chert, and petrified wood, and D:7:264 has Chinle chert, pink chert, and fracture-line chert. This should further support Borger's (1979) contention of enhanced trade opportunities

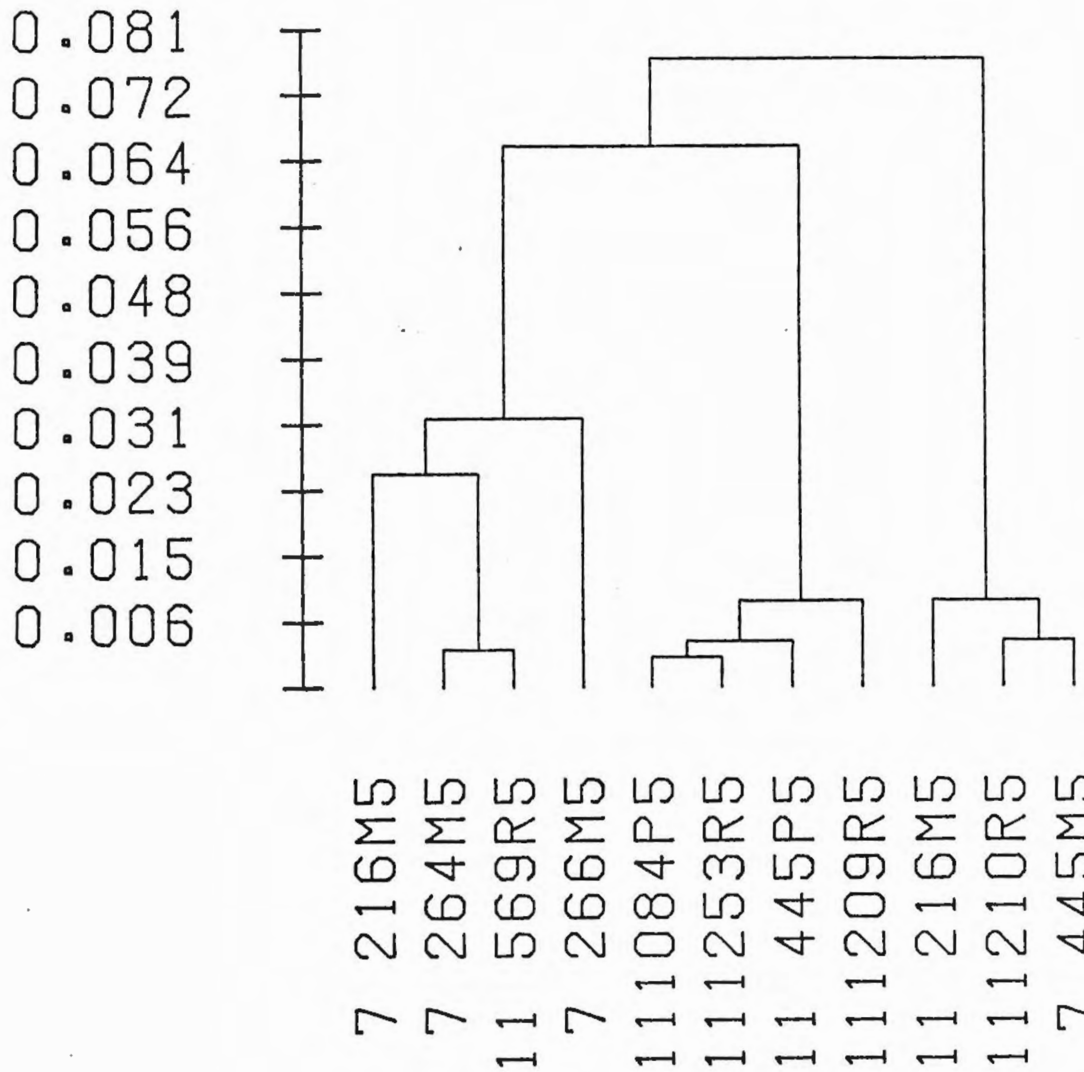


Figure 26. Dendrogram for A.D. 900-949 sites-nonlocal materials.

in Moenkopi Wash. This pattern changes somewhat as exchange ties or information or surplus imports began to be shared around the mesa. However, imports occur more at Moenkopi Wash sites than would be expected by their proportion of the total sample of sites.

The nonlocal materials cluster analysis for the A.D. 950-999 sites differs substantially from the earlier ones (see Figure 27). Cluster II will be discussed first, as it has only two sites (one from Red Peak Valley and the other from Dinnebito Wash). These sites have high percentages of Owl Rock materials (55%) and Navajo chert (17%) and no other nonlocal materials. It is not unusual for sites to have none of the very distant imports, but a complete absence of gravels is uncommon. Cluster I has the remaining nine sites (five from Reed Valley, two each from Red Peak Valley and Moenkopi Wash). At these sites, with mainly local materials, there are only moderate amounts of nonlocal cherts. Only three of the 11 sites had imports. Moenkopi Wash, Red Peak Valley, and Reed Valley all are represented in this trio, but the Moenkopi Wash site, D:7:274, is the only one with more than one type; it has pink chert and creamy opaque.

The following discussion is suggestive for future research but does not have a solid foundation in the evidence at hand because not all sources have been pinpointed as yet. Prior to A.D. 999, sites with more than one rare import had imports that originated in the same general direction (except for pink chert, which, if fracture-line chert were not available locally, has the source closest to the mesa). For example, D:11:569 has both basalt and Chinle chert. Basalt may have been procured near Flagstaff, and Chinle chert was available on the way, near

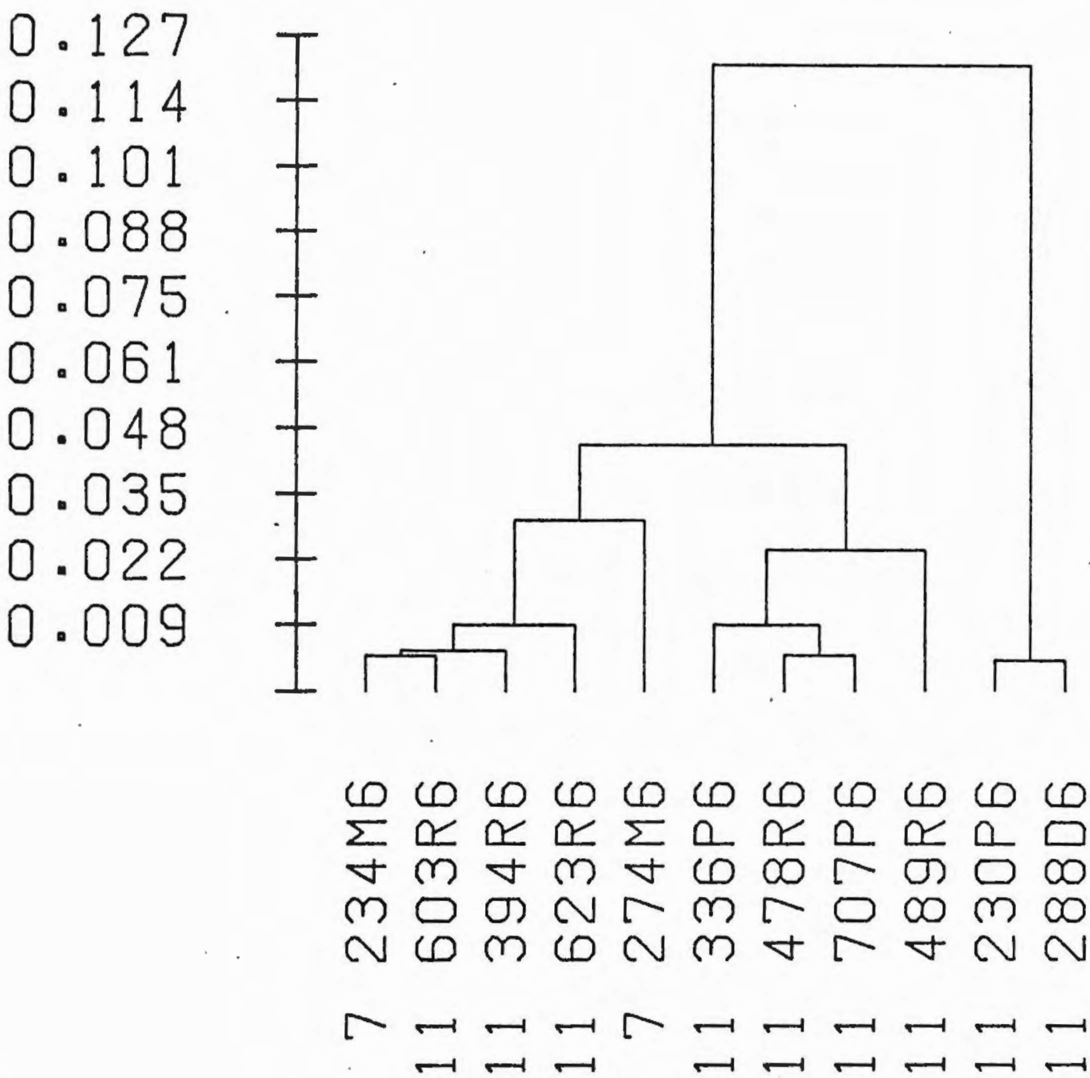


Figure 27. Dendrogram for A.D. 950-999 sites-nonlocal materials.

Cameron. If it could be substantiated, this evidence would be more suggestive of direct access by Black Mesa residents to these sources or to trade or information ties that were limited, as opposed to the evidence from later sites of raw materials from widely separated sources occurring at the same site.

Sites from A.D. 1000-1049 are useful in depicting the opposite pattern. Ten of the 14 sites have imports. All of the rare imports except vitreous petrified wood are represented at these 10 sites. Moenkopi Wash sites are no longer in the majority; there are four of them, four Reed Valley sites, and two Dinnebito Wash sites. It is at this time that the use of rare imports really spread across the mesa, with the exception of Red Peak Valley, which is included during the next period. There is much sharing of raw materials; sites from different drainages have Government Mountain obsidian (Lee Sappington, personal communication), two sites from Moenkopi Wash have pink chert, two sites from different drainages have fracture-line chert, two sites from Reed Valley and Dinnebito Wash have Chinle chert, and four sites from the three drainages have creamy opaque material. Granted there are at least three more sites during this period (n = 14) than during any period preceding it, but the number of sites with rare imports (10 of 14) and the amount of sharing that is evident surpasses that for which increase in cases could account. Chinle chert and creamy opaque both are found at three sites and are from sources in opposite directions; Chinle chert is from the southwest, and creamy opaque from the northeast. More intensified interaction among Black Mesa sites is the most parsimonious explanation for the increased availability of these rare imports to sites on the mesa and the use of materials from distance sources in directions opposite one another.

Owl Rock's predominance seems to be the discriminating feature between the two clusters generated by the nonlocal materials run for the A.D. 1000-1049 sites. Cluster I has only 15% Owl Rock, whereas Cluster II has 45%. There also is more Navajo chert in the second cluster, but fewer cherts from gravels than in Cluster I. Breakdown by drainage is about the same for these two clusters as for the earlier cluster analyses for this time period (see Figure 28).

Two clusters also were isolated in the nonlocal materials analysis for A.D. 1050-1099 sites (see Figure 29). Again they are differentiated principally on their amounts of Owl Rock (Cluster I = 51%, Cluster II = 19%). In addition, it seems that the already low frequencies of the most distant materials are decreasing. They were at 43% of the A.D. 1000-1049 sites, but are only at 25% of the A.D. 1050-1099 sites. It seems interesting that although there are more sites during this period than any other, only two clusters were formed for the local and nonlocal material runs, as opposed to three clusters for several of the other time periods.

The same trend observed among the A.D. 1000-1049 sites continues during the period A.D. 1050-1099. Nine sites from all drainages (n = 20) have imports. Three sites from two drainages have fracture-line chert, three sites from three drainages have vitreous wood, Chinle chert is at two sites in Red Peak Valley, and creamy opaque material is at three sites in two different drainages. Material combinations include obsidian (SW) and fracture-line chert (NE), vitreous wood (SE)

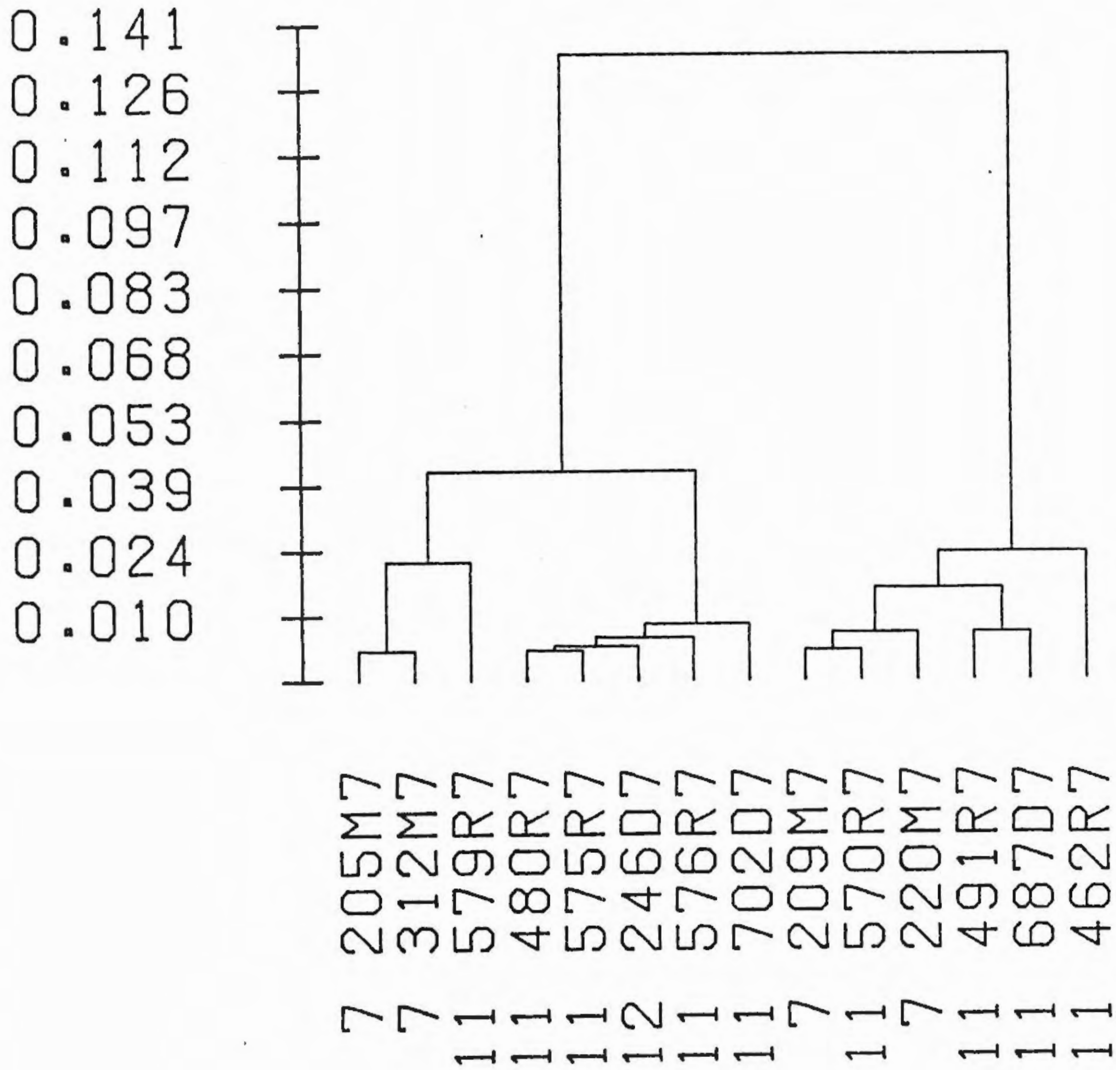


Figure 28. Dendrogram for A.D. 1000-1049 sites-nonlocal materials.

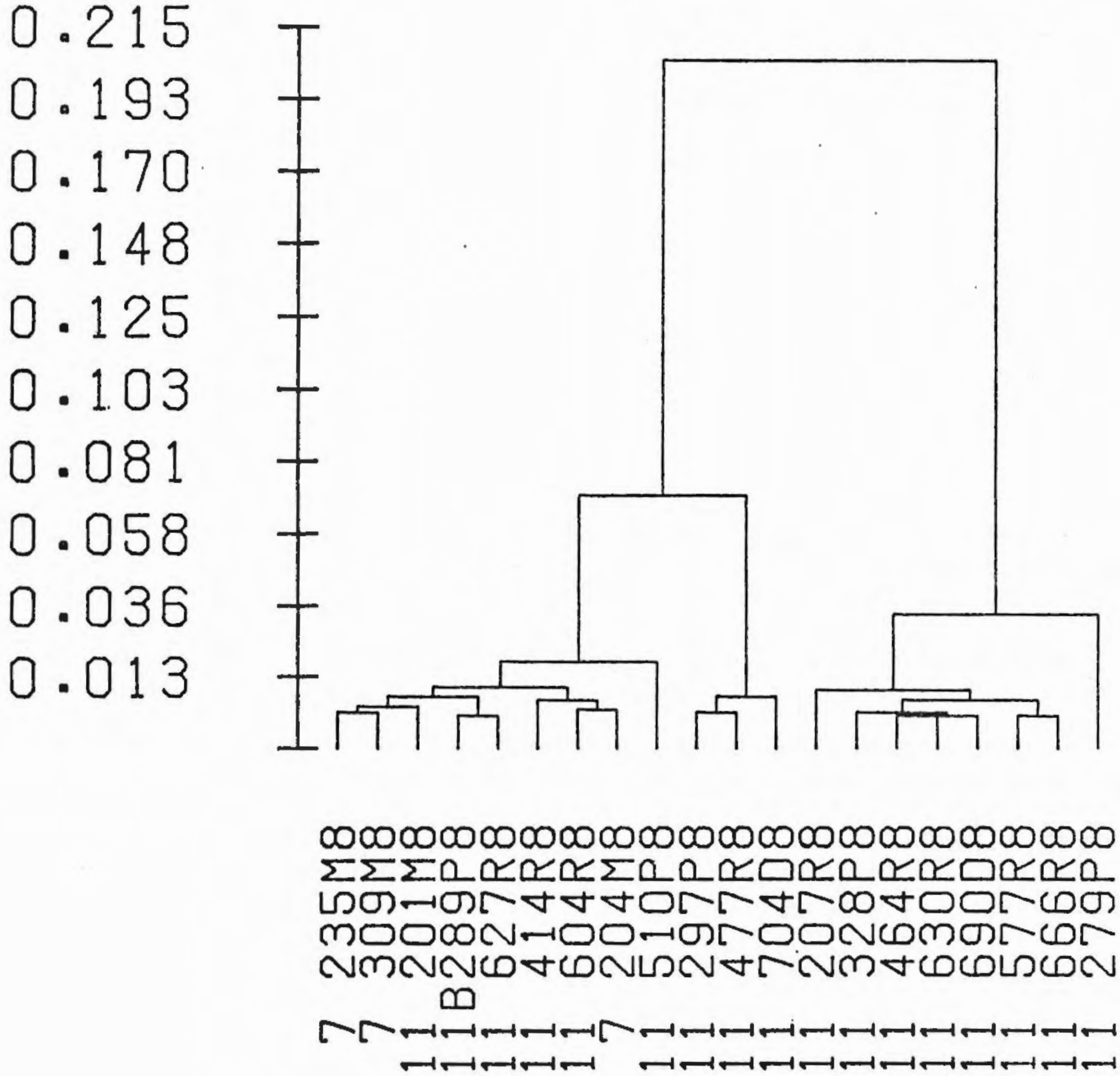


Figure 29. Dendrogram for A.D. 1050-1099 sites-nonlocal materials.

and fracture-line chert (NE), and vitreous wood (SE) and creamy opaque (NE).

The last period, A.D. 1100-1149, has only four sites, two of which, from Red Peak Valley and Moenkopi Wash, have Chinle chert. The first site, D:11:331, also has fracture-line chert. Although on a smaller scale, the pattern is essentially the same.

Weight as the Measure of Abundance

Cluster analyses were conducted with percent of total weight as the input variable also. This was done in an effort to determine whether percent of frequency presented an adequate picture of the distribution of raw materials across sites. Because it was done mainly for comparative purposes, the three separate runs for combined materials, local materials, and nonlocal materials were processed for all sites only.

The results were very similar to those for the cluster analyses by frequency (see Figures 30-32). The departures from the original patterns are generally understandable in light of the modes of occurrence and relative densities of materials (probably caused by composition and molecular structure). For example, white baked siltstone usually fractures naturally into small pieces only a few centimeters long and often less than a centimeter thick. Its white color is due to the absence of iron, and the majority of pieces weigh less than a gram. Sandstone, on the other hand, occurs in massive form; most flakes probably would weigh above average. Materials like local petrified wood, baked sandstone, and quartzite, which generally were chosen as

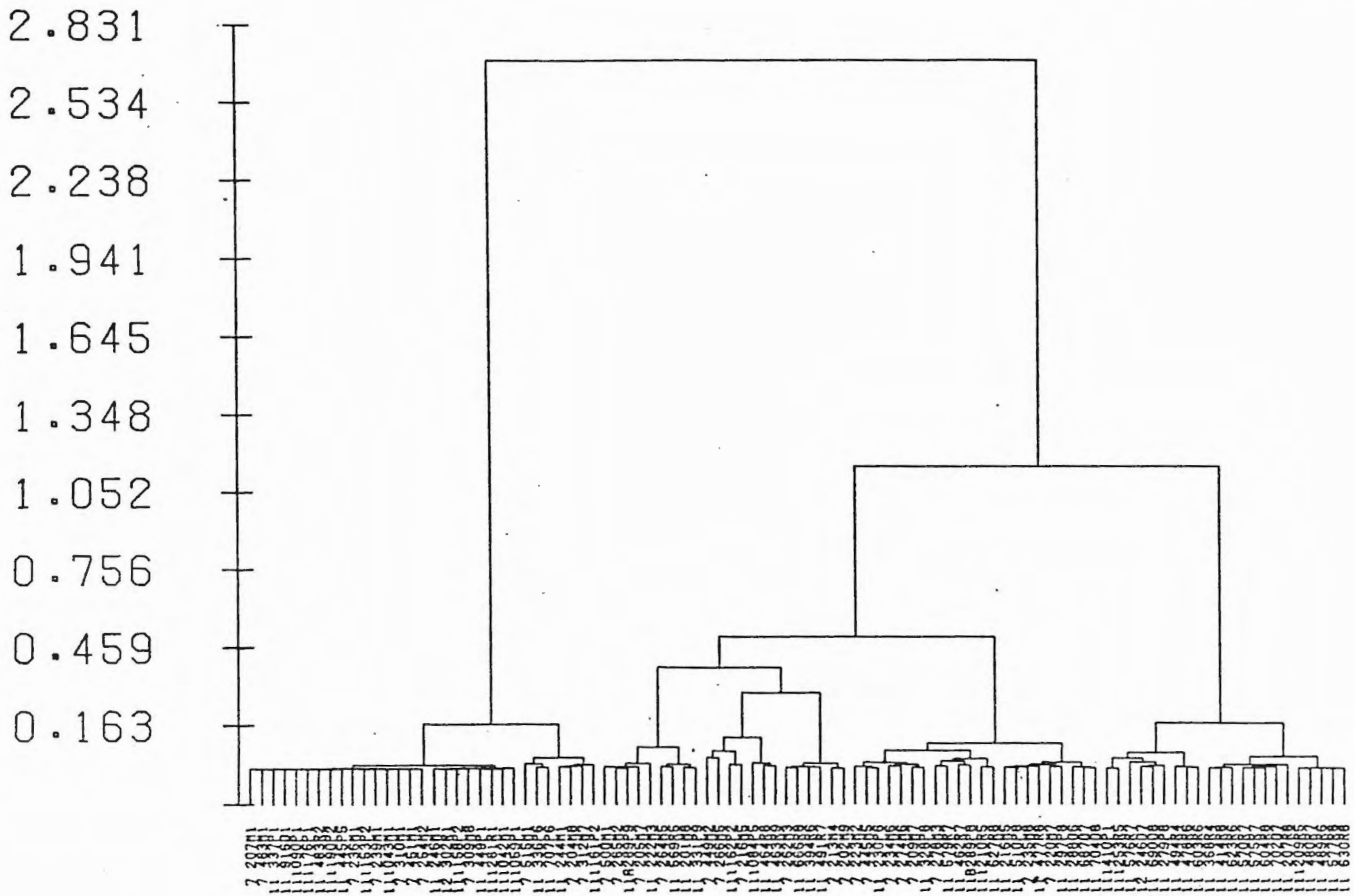


Figure 30. Dendrogram for percent weight (all materials, all sites).

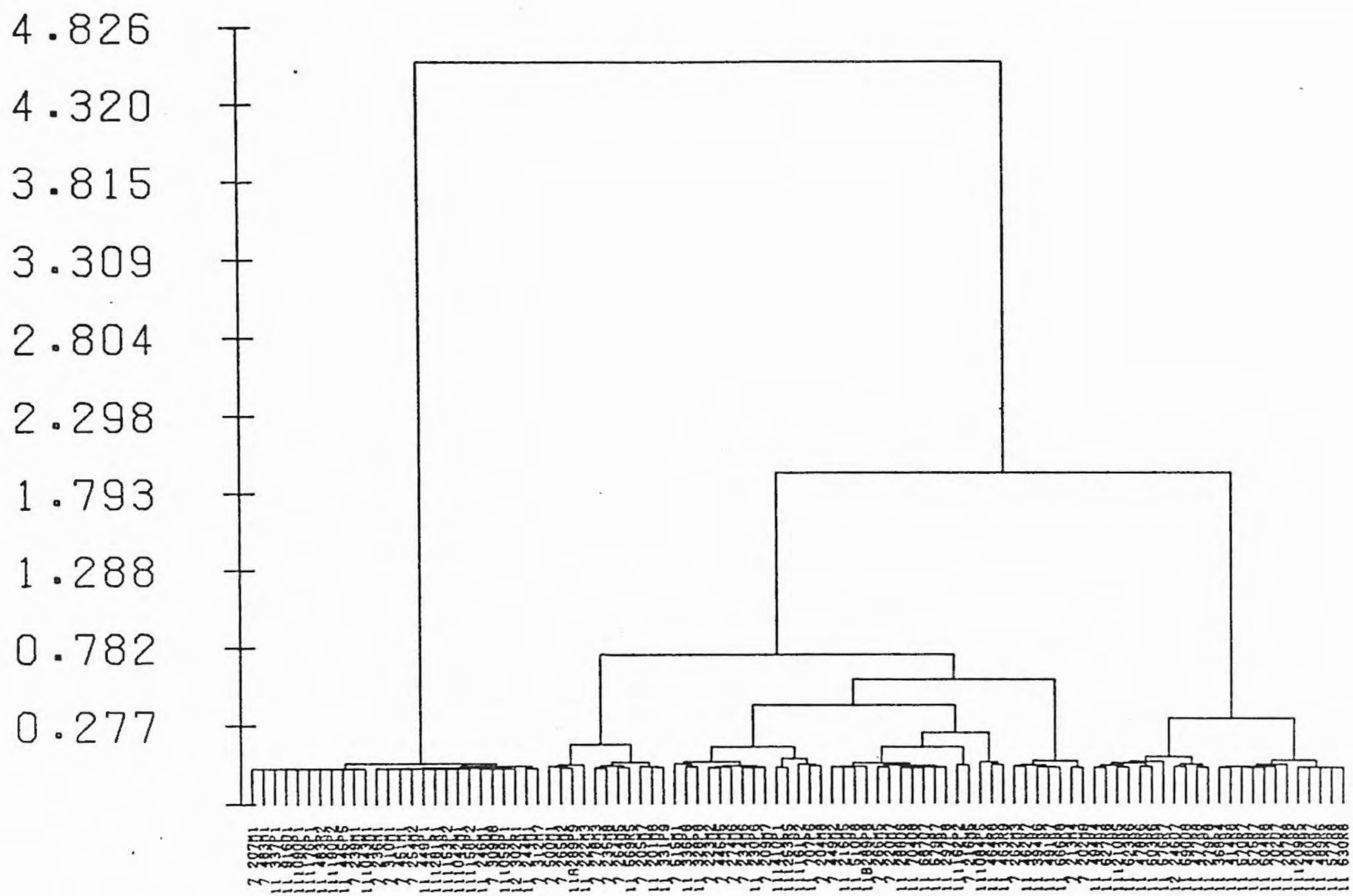


Figure 31. Dendrogram for percent weight (local materials, all sites).

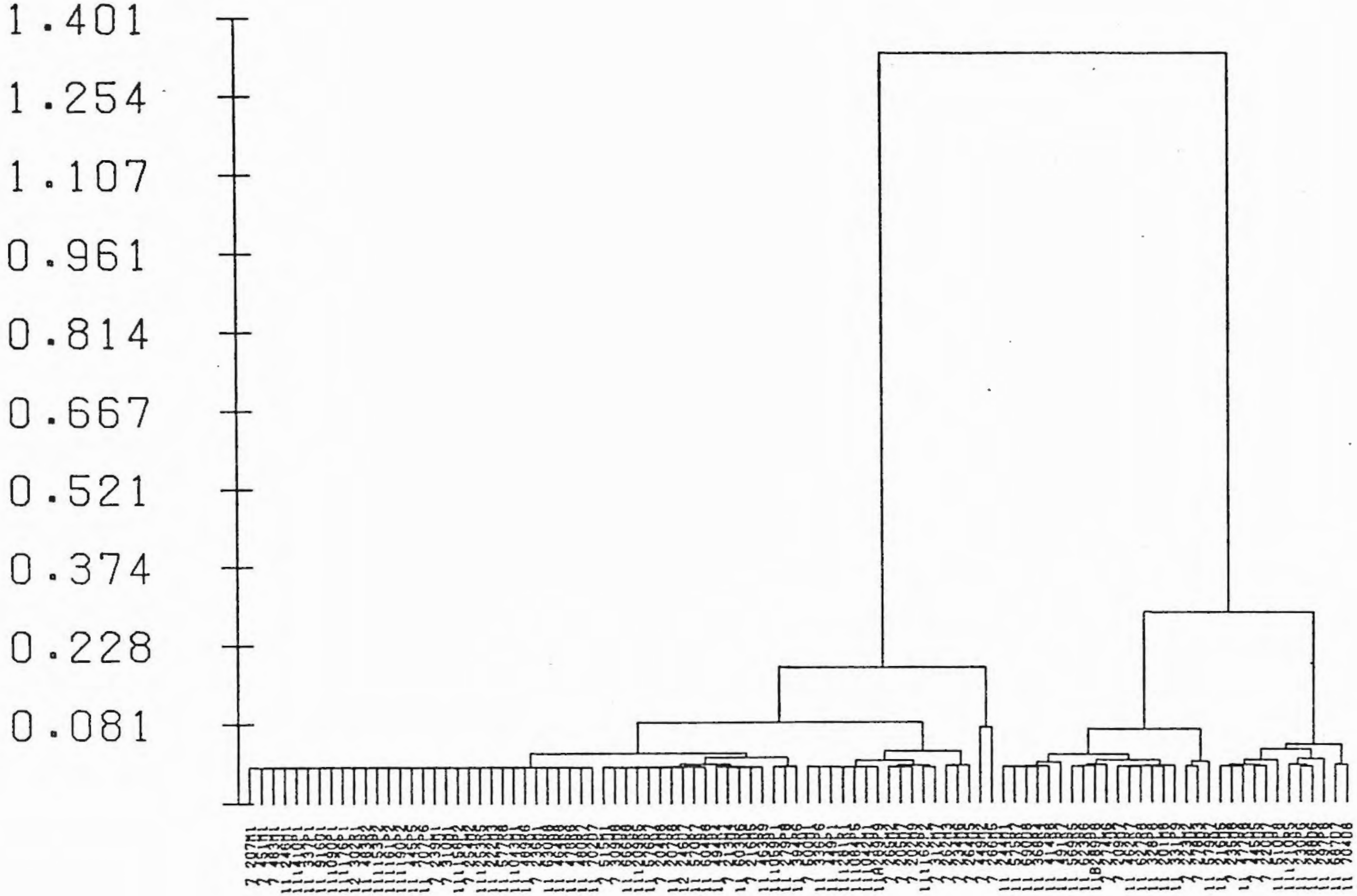


Figure 32. Dendrogram for percent weight (nonlocal materials; all sites).

hammerstone materials, often are found at sites in the form of these large tools. Even when found in smaller pieces they weigh more than equal sized pieces of white baked siltstone because of their greater density.

Thus, depending on which raw materials are present, the percentage of weight may be underestimated or overestimated because weight is not directly comparable from one material to the next. Other raw material studies that have used weight as the variable for relative abundance have made comparisons within a single raw material type, usually obsidian (Wright 1969).

For example, in the all-sites, all-materials analysis (Figure 30), two clusters were formed. The basis for cluster formation was the same as that in the percent frequency analysis, but seven sites were rearranged between them. Cluster I had 86% baked siltstone by weight (91% by frequency), and Cluster II had a mixture of materials with slightly higher weight percentages for heavy materials than in the frequency percent. The changes that occurred were the deletion from Cluster I of three sites, all of which have high frequencies of white baked siltstone, but low weights of that material, and the addition of four sites with high weights of the colored varieties of baked siltstone. The four sites are from later time periods but are located in areas that might have ready access to the baked siltstone (i.e., in Red Peak Valley and within the lower reaches of Moenkopi Wash). In addition, the local materials are heavier and are more likely to be emphasized by this discrepancy. In view of the already low percentages of the assemblage contributed by the imports, it was decided not to diminish their relative contribution further by using weight as the variable under analysis. Thus, frequency and percent of frequency will be used as the major variable through the remainder of this study.

Cluster Analysis Summary

The cluster analysis revealed several interesting patterns in the data, some of which were expected and some of which were not. The first cluster run, that for all materials and all time, depicted a change over time from almost exclusive use of local material (specifically baked siltstone) to a variety of primarily nonlocal materials (mainly Owl Rock and other cherts). The focus on white baked siltstone has been associated with Basketmaker II sites on Black Mesa (Anderson 1978). Although the time period labels used in this study indicate that the majority of sites that fall into the white baked siltstone cluster either have not been dated or have been dated to A.D. 793, arguments were provided earlier that strongly suggest that all of these are Basketmaker or generally early sites. The gap in occupation of Black Mesa sometime between A.D. 1 and A.D. 800 serves to accentuate the abruptness in the change from almost purely local material to a variety of materials in the assemblages.

Whatever the reason for this change, it gives us a simple baseline from which to trace the development of exchange ties, for virtually none of the rare imports are present at these early sites. Before summarizing the character of the development of these exchange ties, another pattern, which was totally unexpected and, therefore, particularly intriguing, should be mentioned.

A cluster was recurrent through many of the analyses for all materials and local materials and was composed entirely of Reed Valley sites. This cluster was formed on the basis of high percentages of sandstone in the assemblages. Reed Valley sites did not cluster, however, in the analyses of nonlocal materials, so the phenomenon does not appear to have been related to interaction. If it had been, the sites should have shared in the use of nonlocal materials as well. Instead, some other factor(s) must have been the cause. Through a series of chi-square tests it was found that there is a significant association between numbers of rooms and ground stone artifacts on sites in the different drainages. Reed Valley (and, to a lesser extent, Dinnebito Wash) sites had higher than expected values for these categories. There is a trend for more of the later sites to occur in these areas as well. The unusually high proportions of sandstone lithics may be related to house construction, ground stone manufacture, and/or chipped stone manufacture. Additional work needs to be done to associate this debitage with one or all of these activities and to understand why more of the later sites are located in Reed Valley than elsewhere.

The use of Moenkopi Wash as a chipped stone raw material exchange route demonstrated by Borger (1979) for post A.D. 800 sites was confirmed by the cluster analysis and extended back in time to the earliest occupation of the mesa. This area has the earliest evidence for most of the materials imported to the mesa and has the highest percentage of sites with these imports. Cluster analysis means (Appendix D) indicated that besides having more of the imported cherts, these sites also have greater proportions of the quartzes and local petrified wood, usually used as hammerstones. This appears to be a meaningful correlation because the hard hammer materials are necessary for initial chert reduction, but not in the manufacture of baked siltstone artifacts, where wooden or antler batons were more suitable.

According to the results of the cluster analysis, the exchange ties for the acquisition of chipped stone raw materials from distant sources develped along very predictable lines. During the two earliest periods, i.e., undated and A.D. 793, there were virtually no rare imports at sites, and assemblages were composed almost exclusively of baked siltstone. During the A.D. 793 period there were a few sites with high proportions of chert and hammerstone materials in their lithic assemblages; these sites were located in the Moenkopi Wash area.

Beginning with A.D. 800, the first sites occupied after the supposed gap in settlement, baked siltstone decreased to a negligible amount and cherts made up the bulk of the assemblages. Several of the rare imports were found on sites, but generally they did not occur at more than one site (i.e., trade ties were not shared) and usually there was only one rare import at a site. When there were several rare imports at a single site, they all had sources in the same direction (e.g., Chinle chert, basalt, and vitreous petrified wood all have sources to the south). The Reed Valley sandstone phenomenon began at about the same time that masonry began to be used in construction. This basic pattern continued through A.D. 999 with imports from distant sources in different directions at separate sites. The Reed Valley sandstone cluster persisted, and a few sites had higher percentages of baked siltstone (mainly the gray variety) than cherts.

Chinle chert and creamy opaque materials and others with distant sources in different directions appeared together at sites for the first time beginning A.D. 1000-1049. This pattern continued through A.D. 1099, after which local materials became more important again, creamy opaque no longer occurred at sites, and Owl Rock chert declined in frequency.

Thus, the cluster analysis indicates first the almost exclusive use of local materials, then the gradual introduction of rare imports to individual sites, the eventual sharing of specific rare imports among sites, and finally the sharing by many sites of most of the rare imports. This last step, with rare imports in varying combinations regardless of direction to source, helps support the hypothesis for increased interaction among Black Mesa sites. The alternate explanation is that each of the Black Mesa sites developed these exchange ties individually for each of the materials. The period when the system supposedly began to break down, after A.D. 1100, is a time when rare imports declined and frequencies of local materials increased again. Thus, the cluster analysis was useful (1) in identifying previously unrecognized patterns, as with the Reed Valley sandstone cluster, (2) in supporting the results of earlier studies, as with the Moenkopi exchange route (Borger 1979), and (3) in defining patterning consistent with the predictions of the model of increased interaction.

Second Examination--Principal Components and Factor Analysis

Methodology

Cluster analysis results indicate that inhabitants of Black Mesa sites procured raw materials available off the mesa independently at first and, over time, use of the materials spread across the mesa. The patterns observed are intriguing but are based on less than optimal sample sizes. These patterns should be supported by another statistical approach if they are real. Factor analysis was chosen to group the variables in order to determine which raw materials, if any, are associated regularly in the assemblages.

In keeping with the cluster analysis results, it is expected that lithic assemblages from sites dating to the early period will have high proportions of local material and, if distant material is present, it usually will be of a single type. Procurement ties for nonlocal materials are expected to have been relatively undeveloped at the early sites; materials with sources in different directions should not appear at the same sites. Sites from the middle of the time range are expected to have more of the distant materials than the early sites. They may have several types but are not expected to have materials from both the north and the south. If more than one distantly obtained raw material is at a site from the middle time range, the materials should have sources in the same direction, reflecting an orientation to people or places in a single direction. Thus, the case for external ties having been maintained separately by the inhabitants of different Black Mesa sites is supported when materials from sources in different directions do not appear in the same assemblages. The case for ties with specific source areas is enhanced when raw materials available at great distances and in the same direction are found together at Black Mesa sites. Sites in the latest time period are expected to have a mixture of materials as evidence of more intensified interaction among sites on the mesa.

It should be emphasized that no assumptions are made as to whether material was obtained through trade, either with neighboring Black Mesa sites or with those in the source area, or through direct access to the material at its source. Increased access by Black Mesa inhabitants to the various materials may have been gained through increased information flow concerning trade contacts and/or source locations or through exchange between sites on Black Mesa. Whether it was information flow or flow of material goods is not critical for this analysis; the evidence for increased interaction among sites on Black Mesa is what is important. The assumption will be made, however, that the ability to procure materials from distant sources, through whatever means it ws accomplished, was not developed individually by each site on Black Mesa. It is, of course, a possibility, but it would have been akin to reinventing the wheel. Thus, combinations on sites of distant imports from different directions will be accepted as evidence of increasing interaction among Black Mesa sites.

Time will be controlled, but in order to keep sample sizes adequate and to have the number of cases larger than the number of variables, only gross temporal distinctions will be made. The major periods of change, as delimited by the cluster analysis, will be used to group the sites. Thus, sites in the undated and A.D. 793-dated groups form the first major time period (31 sites), those dating from A.D. 800-999 are in the second period (28 sites), and those dating from A.D. 1000-1150 form the third group (38 sites).

Before discussing the results it will be useful to provide some more specific information on the factor analysis procedures followed in this study. These tests also were run on the ASU Amdahl 470 computer. The factor analysis program is from the BMDP library and was written by James Frane of the Health Sciences Computing Facility at the University of California at Los Angeles (Dixon and Brown 1979).

Factor analysis is a set of statistical techniques used to find clusters of attributes, in this case raw materials. Exploratory factor analysis attempts to reduce a set of variables into fewer "factors" or hypothetical variables. In confirmatory factor analysis several underlying variables may be hypothesized and then tested to see if the observed variables segregate themselves in the manner expected (Kim and Mueller 1978). Most factor analyses are in the gray area between exploratory and confirmatory and this is no exception. In this case, it is expected that materials available at some distance to the north, i.e., creamy opaque, pink chert, and possibly fracture-line chert, may have been procured together, and likewise materials from the south, i.e., Chinle chert, obsidian and probably basalt, and vitreous petrified wood. Materials available on Black Mesa (coarse-grained petrified wood, vein quartz, quartzite, sandstone, siderite, iron concretions, baked sandstone, and all color varieties of baked siltstone) and gravels, Owl Rock materials, and Navajo chert may be included with either or both groups because they are available nearby.

The data input were the percentages of each assemblage composed of the original ungrouped raw material types (see Appendix C). Because source directions, not just relative distances, were critical for this phase of the analysis, it was decided not to group the low frequency variables prior to the computer analysis as was done for the cluster analyses. This made the collapsing of time periods, mentioned above, necessary.

The first step in the factor analysis program is to group the variables, in this case using the principal components method. The intent in this analysis is to investigate the dependencies among variables, and a matrix of correlation coefficients is used to this end. The data points can be viewed as a swarm located on a graph in two-dimensional space (x and y axes) for two variables (n-dimensional space for n variables). Since the intent is to summarize as much of the variability as possible, the first axis is rotated so it passes through or closest to the largest number of points. The second axis will be perpendicular to the first (and with n variables it will pass through or near the next highest number of points). Being perpendicular (orthogonal) to the first axis means that the components are uncorrelated. There will be as many new axes or components as there were variables so all the original variance in the data set is explained. However, it often turns out, especially if the original variables were highly correlated, that a smaller number of components is adequate to describe most (70-90%) of the original variability.

The amount of the original variance for each original variable (i.e., raw material type) explained by a particular component is its loading on that component (referred to as its factor loading). Factor loadings range from +1 to -1. A rule of thumb for determining which variables made significant contributions to the establishment of a factor is to retain any with factor loadings with absolute value greater than or equal to .400. The square of this figure indicates the percentage of the variance for that variable explained by the factor (Binford and Binford 1966). It sometimes is preferable for clarity to choose a higher factor loading such as .500 as the cutoff point because it indicates that the factor explains 25% of the variance for that variable and is not as likely to be a spurious correlation. The .500 cutoff point will be used in this study. It is recognized that factor loadings as high as .900 may be spurious; thus factor composition will be inspected closely for this possibility.

Factor loadings marked with an asterisk (*) in Tables 14, 16, and 18 are those that determined the factor. The meaning attributed to the combination of variables in a given factor is provided by the researcher based on characteristics of the variables. For example, reasons for combinations expected in this analysis include source locales in close proximity to one another and/or selection for the manufacture of implements used for the same function. Inversions, i.e., high positive and negative factor loadings that determine a factor, indicate some kind of inverse relationship between the high positive and high negative loadings (Doran and Hodson 1975). Raw material procurement patterns may have changed over time or there may have been functional differences between sites. The utility of these explanations should be minimal, however, because an attempt has been made to control for time (although only gross temporal distinctions have been made) as well as to exclude limited activity sites from the analysis (see Chapter IV). Inversions also may indicate, in the case of widely separated sources for two materials, that when one was utilized, the other was not. Because percentages were input and they form a closed array, there will be positive and negative factor loadings for each factor in this analysis; whether or not these inversions determine the factor depends on their magnitude. The use of a closed array (percentages) with a low number of variables may prove problematical because the values do not vary independently of one another. However, the minimum number of variables in these tests is 17; thus the problem should be minimal.

The sum of the squares of the factor loadings on a particular component, its eigenvalue, is the amount of the original variance explained by that component. The eigenvalue is used to determine how many components are enough, i.e., what constitutes an adequate summary of the original variables. Three rules of thumb for this decision are: (1) a dramatic drop-off in the plot of the eigenvalues suggests that components before the drop-off should be used; (2) components with eigenvalues greater than 1.00 should be used; or (3) components that explain a certain cumulative percentage of the variance should be retained (Doran and Hodson 1975:200). Rule #2 is most commonly employed and is the default option of the BMDP factor program so it was applied here. It generally turns out that components with eigenvalues equal to or greater than 1.00 explain 70-90% of the variance anyway.

Once the principal components are identified, the remainder are deleted from the analysis and the factor loadings of the variables on the principal components are rotated in order to arrive at a more direct interpretation for them. Once the factor loadings are rotated, the axes are referred to as factors rather than components. The procedure used here for rotation, also the default option, is Varimax rotation, which maintains the right angles (indicating no correlation) between factors. Each site is given a factor score for each factor. The scores are standardized and those larger than + or -1 generally are considered to have made a significant contribution to the establishment of that factor. In discussing the output, the makeup of the factors will be presented first and then the factor scores on the sites will be analyzed.

The clearest way to present the factor scores for each site is in scattergram form with one factor on the x-axis and another on the y-axis. The scattergram program employed here was written by Frank Aldrich of the Geography Department at Arizona State University and is part of the GEOLIB series of programs. The scattergrams generated for this study are included with the text. Symbolism that depicts the drainage in which each site is located is on each scattergram. Thus, spatial patterns should be easy to detect. It must be noted that extreme scores, usually a single one per scattergram, were reduced but maintained as the highest or the lowest score(s), in order to maximize separation of the main group of points. The actual factor scores are presented in Appendix E.

Factor Analysis for Time Period I (undated and A.D. 793)

The first factor analysis was on the 31 undated and A.D. 793-dated sites. Only 17 of the 28 raw material types are represented at these sites; the remainder were deleted from this run (see Table 12 for materials included in each factor run and the code for each material used on Tables 14, 16, and 18).

Significance probabilities for the correlation coefficients were taken from Table A.11 in Thomas (1976:508). Correlations significant above the .05 level (r < .3557) were ignored. The simplified correlation coefficient matrix is presented in Table 13. In the following discussion, correlation coefficients significant above the .01 level (r < .4563) will not be considered. The correlation matrix indicates significant positive correlations between sandstone and pink baked siltstone (.881), pink chert and gray chert gravel (.861), Owl Rock chert and brown chert gravel (.779), baked sandstone and chalcedony (.626), Owl Rock chert and gray chert gravel (.682), chalcedony and fracture-line chert (.496), and baked sandstone and fracture-line chert (.466). These correlations are between local materials, a local material and an intermediate material, two intermediate materials, an intermediate and a distant material, and a local and a distant material. Significant negative correlations exist between white baked siltstone and gray baked siltstone (-.610), two local materials, and white baked siltstone and Owl Rock chert (-.582), a local and an intermediate material. Because these are the basis for the factors, they will be discussed more fully below.

Eight of the 17 components have eigenvalues greater than 1.00 and were rotated. These explain 85% of the original variance, which is well within the acceptable (70-90%) range. The eight rotated factors will be analyzed for their most important variables (those with factor

Table 12. Raw Materials Included in Each Factor Analysis

Raw Material	Code	Undated and A.D. 793	A.D. 800–999	A.D. 1000–1150
Local				
Local petrified wood	4	X	X	X
Vein quartz	5		X	
Quartzite	9		X	X
Sandstone	13	X	X	X
Siderite..................	18		X	X
Baked sandstone	23	X	X	X
Iron concretions	29	X	X	X
White baked siltstone	71	X	X	X
Gray baked siltstone	72	X	X	X
Pink baked siltstone	73	X	X	X
Yellow baked siltstone	74			X
Intermediate				
Chalcedony	1	X	X	X
Pink chert	28	X	X	X
Brown Navajo chert	30	X	X	X
Red, white, & blue Navajo chert	35		X	X
White Navajo chert	37	X	X	X
Owl Rock chert	40	X	X	X
Purple-white chalcedony/chert	45	X	X	X
Gray chert gravel	50	X	X	X
Brown-yellow chert gravel .	55	X	X	X
Quartzitic chert	59		X	
Oolitic chert	60		X	X
Distant				
Vitreous petrified wood ...	53	X	X	X
Fracture-line chert	57	X	X	X
Creamy opaque	58		X	X
Chinle chert	63		X	X
Obsidian	6			X
Basalt	7		X	X
Total		17	26	26

Table 13. Simplified[a] Correlation Coefficient Matrix for Undated and A.D. 793 Sites Factor Analysis.

Raw Material	Raw Material						
	Sandstone	Baked Sandstone	Iron Concretions	White Baked Siltstone	Gray Baked Siltstone	Pink Baked Siltstone	White Navajo Chert
Sandstone							
Baked sandstone.							
Iron concretions							
White baked siltstone		-.418					
Gray baked siltstone				-.610			
Pink baked siltstone	.881						
White Navajo chert							
Owl Rock chert .		.367		-.582			
Purple-white chert			.428				
Chalcedony		.626		-.391			
Pink chert							
Gray chert gravel				-.454			
Brown chert gravel							.420
Fracture-line chert		.466					

Table 13 (Continued)

Raw Material	Raw Material					
	Owl Rock Chert	Purple-White Chert	Chal-ce-dony	Pink Chert	Gray Chert Gravel	Brown Chert Gravel
Sandstone						
Baked sandstone ..						
Iron concretions						
White baked siltstone						
Gray baked siltstone						
Pink baked siltstone						
White Navajo chert						
Owl Rock chert ...						
Purple-white chert						
Chalcedony						
Pink chert	.364		.403		.861	
Gray chert gravel	.682					.440
Brown chert gravel	.779					
Fracture-line chert			.496			

[a]Coefficients not significant at the .05 level (.3557 or greater) have been omitted.

loadings greater than or equal to .500) (see Table 14). The first six factors were derived from material combinations observed in the correlation matrix.

Pink chert and gray chert gravels have very high loadings on Factor 1. The former has been found only in gravels near Church Rock in the Kayenta area, and the latter occurs there as well. It may represent a Kayenta import factor, but there is only one site with pink chert. Baked sandstone, fracture-line chert, and chalcedony have very high loadings on the second factor. Baked sandstone is available locally and usually is used for hammerstones. Fracture-line chert, if not available on Black Mesa, can be found to the northeast, where chalcedony can be obtained also. This factor, too, may represent materials available to the northeast, but includes hammerstone material that may have been used in the manufacturing process as well. It is interesting that even though the materials from Factors 1 and 2 are available in the same direction, they are not associated regularly enough to figure prominently in the same factor at this early time. The two distant imports actually occur only rarely at these sites, so their importance in determining the factors probably has little meaning. If the patterns are meaningful, these materials may become associated as interaction increases.

The scattergram for Factors 1 and 2 (see Figure 33) indicates the majority of sites have little or none of these materials. There are three outliers; two (D:11:1162 and D:7:265) have high scores on Factor 2 but low scores on Factor 1. The other (D:7:449) has a high score on Factor 1 (it is the only site during this period with pink chert) and a moderate score on Factor 2. With the exception of D:11:1162, located in

Table 14. List of Variables Arranged According to a Descending Order of Factor Loadings: Factors 1-8 for Undated and A.D. 793 Sites

Factor 1		Factor 2		Factor 3		Factor 4	
Material Code	Loading	Material Code	Loading	Material Code	Loading	Material Code	Loading
Factor Loadings							
28	.978*	23	.854*	55	.958*	73	.966*
50	.897*	57	.811*	40	.805*	13	.955*
40	.439	1	.790*	37	.593*	55	.002
1	.362	40	.230	50	.393	57	.002
23	.073	28	.063	23	.132	72	-.011
55	.057	50	.015	72	.035	45	-.018
30	-.006	53	-.031	29	.028	28	-.026
45	-.012	13	-.042	53	.010	23	-.031
13	-.018	30	-.043	13	-.016	53	-.031
53	-.021	73	-.046	57	-.035	40	-.038
4	-.034	55	-.049	45	-.056	50	-.042
73	-.041	45	-.064	4	-.060	29	-.066
29	-.063	4	-.065	28	-.067	1	-.095
72	-.100	29	-.076	1	-.080	4	-.106
37	-.128	37	-.083	73	-.087	30	-.120
57	-.156	72	-.136	30	-.130	37	-.164
71	-.390	71	-.358	71	-.306	71	-.292
Eigenvalue							
	3.452		2.232		2.064		1.674
Cumulative Proportion of Total Variance							
	.203		.334		.456		.554

Table 14 (Continued)

Factor 5		Factor 6		Factor 7		Factor 8	
Material Code	Loading	Material Code	Loading	Material Code	Loading	Material Code	Loading
			Factor Loadings				
72	.923*	45	.892*	30	.726*	53	.966*
29	.425	29	.706*	23	.139	29	.358
37	.374	71	.047	72	.110	55	.090
30	.179	40	.022	50	.106	71	.053
40	.111	72	.018	55	.105	72	.008
73	.110	57	.012	45	.062	57	.008
1	.094	37	-.001	57	.026	28	.005
23	.025	28	-.001	53	.025	13	-.011
4	.016	53	-.004	73	.015	73	-.025
28	-.011	73	-.007	13	-.010	1	-.025
53	-.014	13	-.036	28	-.034	40	-.028
50	-.030	23	-.038	29	-.059	23	-.031
55	-.040	55	-.044	40	-.083	50	-.037
13	-.053	50	-.053	71	-.125	37	-.099
57	-.137	1	-.124	1	-.222	45	-.148
45	-.144	30	-.243	37	-.268	30	-.155
71	-.703*	4	-.261	4	-.683*	4	-.161
			Eigenvalue				
	1.453		1.338		1.111		1.042
			Cumulative Proportion of Total Variance				
	.640		.718		.784		.845

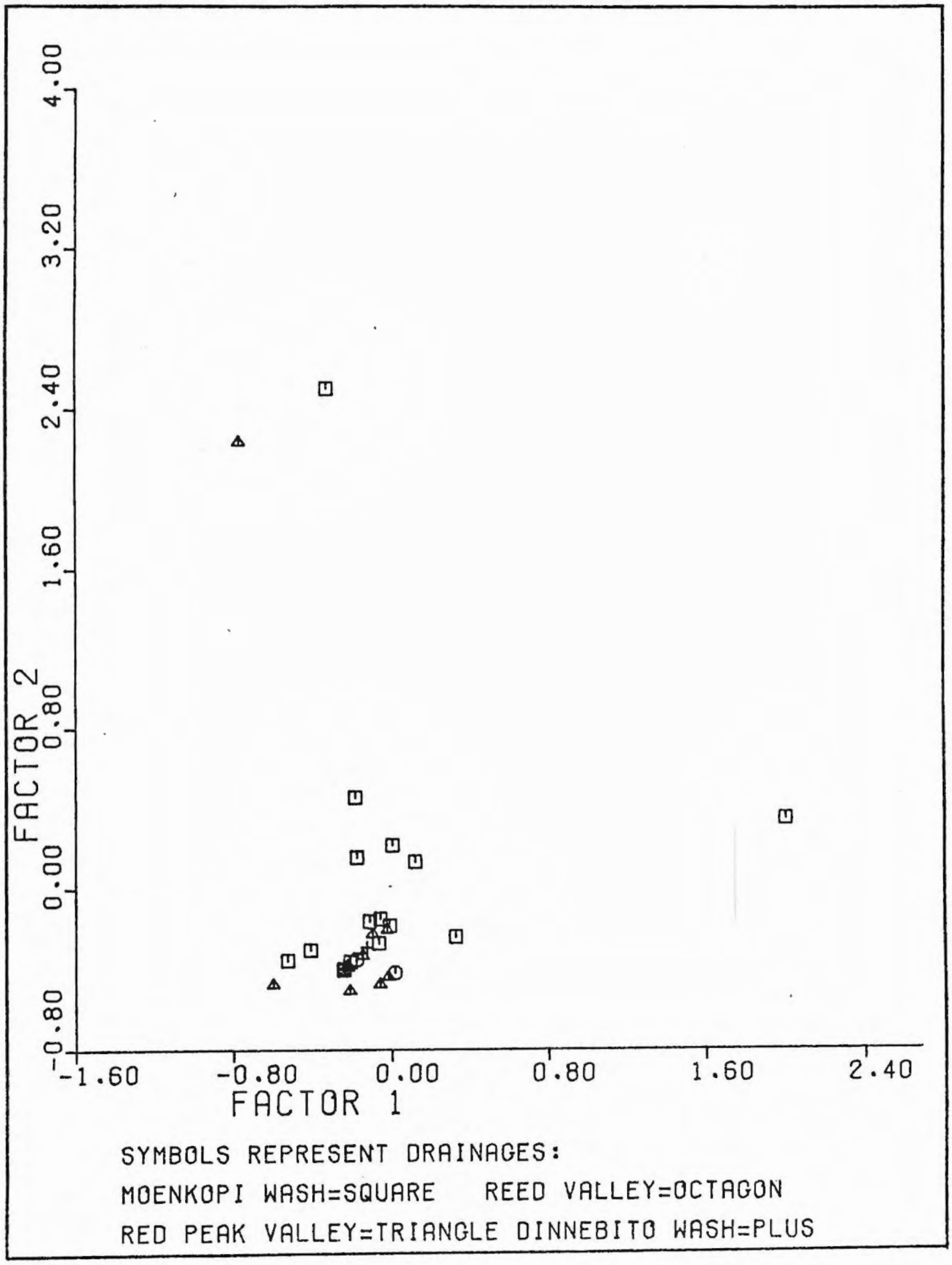


Figure 33. Factor scores for Factors 1 and 2, time period I.

Red Peak Valley, all the sites with positive scores on either of the factors are in Moenkopi Wash. It should be pointed out that D:11:1162 is a multicomponent site and, although every effort has been made to separate the components horizontally, it is possible that the occurrence of these imports in the early component is a result of mixing. Evidence in support of the procurement of nonlocal raw materials at early Moenkopi Wash sites was outlined earlier in the cluster analysis section. Also discussed earlier was the association of two imports at an early site (D:7:449) and the occurrence of a distant raw material, fracture-line chert, at two sites.

Brown chert gravel and Owl Rock chert have very high loadings on Factor 3, and white Navajo chert has a moderate loading on the same factor. Owl Rock and white Navajo chert are located near Black Mesa, and gravels are in all directions, so this factor neither supports nor refutes the proposed outcome. As seen in the scattergram (Figure 34), Red Peak Valley sites have much more varied scores on Factor 3 than Factor 2, but they are subsumed in the range of variability evidenced by the Moenkopi Wash sites on this factor. The two Reed Valley sites are clustered on the negative side for both factors.

Factor 4 is a local factor; pink baked siltstone and sandstone have high loadings on it (although there is only one site with sandstone. Scores on Factor 4 from Moenkopi Wash sites are variable, but mostly are on the negative side, as are Red Peak Valley site scores, with the exception of D:11:1410, also the early component of a multicomponent site (see Figure 35). Factor 5 also is local with a negative association between gray baked siltstone and white baked siltstone. The

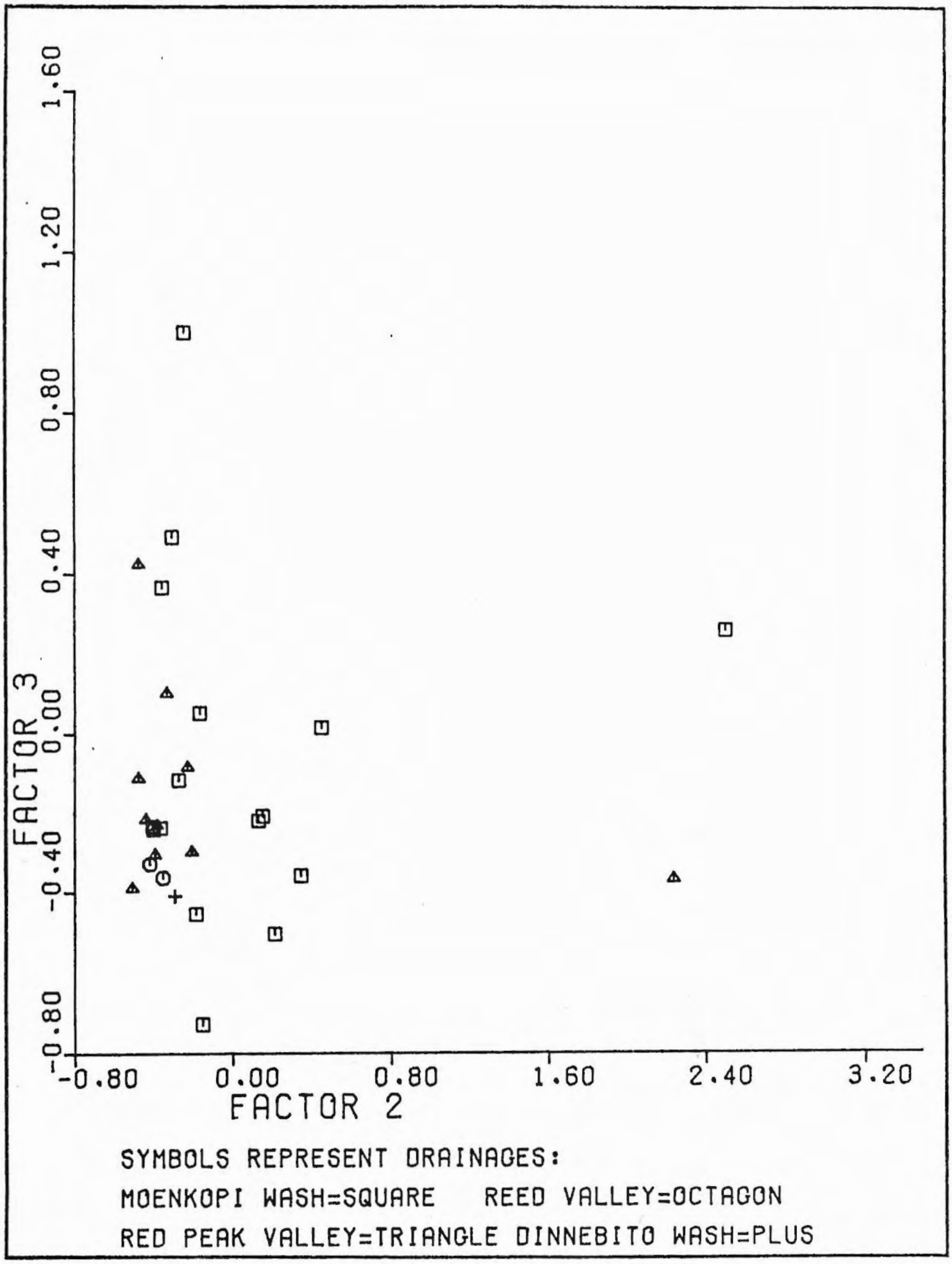


Figure 34. Factor scores for Factors 2 and 3, time period I.

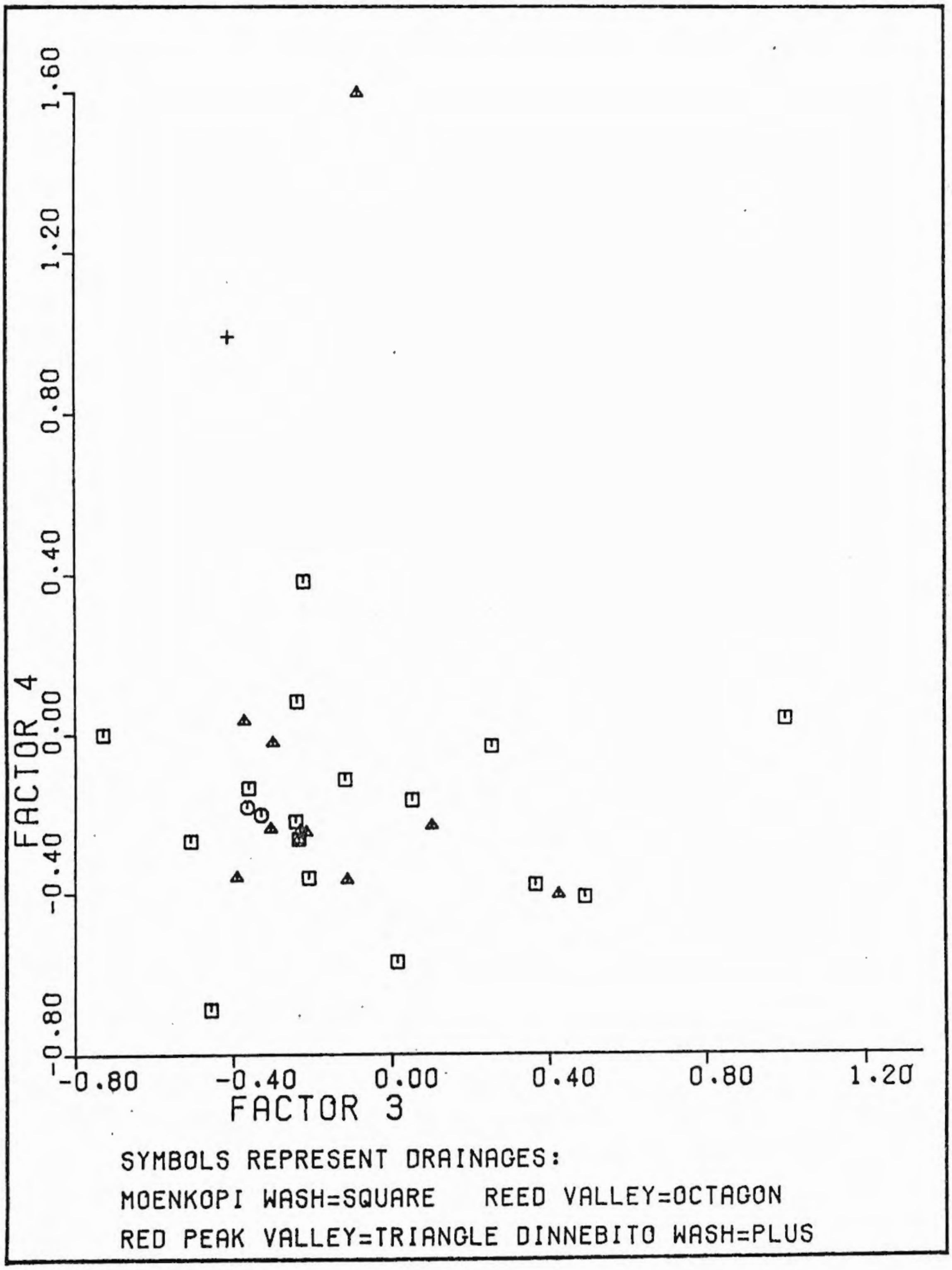


Figure 35. Factor scores for Factors 3 and 4, time period I.

single Dinnebito Wash site (D:11:916) has relatively high scores on both Factors 4 and 5, indicating the importance of local materials in the assemblage. The majority of Red Peak Valley sites have scores of zero or less on both Factors 4 and 5. The two exceptions are D:11:1410, mentioned above, and D:11:1059, which has a significant positive loading on Factor 5 but a negative one on Factor 4. The two Reed Valley sites again are almost identical in their scores on these two factors. Moenkopi Wash sites exhibit the widest range of variability for these factors also (see Figure 36).

Factors 6 and 7 have combinations of cherts available near the mesa and local materials. The correlations in these factors have little meaning because they are based on very low frequencies.

The only import from a great distance, vitreous petrified wood, has a very high positive loading on Factor 8, and it alone contributes significantly to that factor. Only one site, D:7:236, a Moenkopi Wash site, has vitreous petrified wood during this time period, so the factor scores for Factor 8 also are essentially meaningless. Thus, scattergrams for these factors will not be presented.

Distant raw materials are represented in two factors for this time period; all the other factors are made up of materials available locally or at no great distance from the mesa. If the populations at the time were mobile hunter-gatherers, these materials could have been procured during foraging trips off the mesa. No special trade ties or information exchange would have been necessary for their procurement. The two distant raw materials, fracture-line chert and vitreous petrified wood, are available in different directions and were significant in

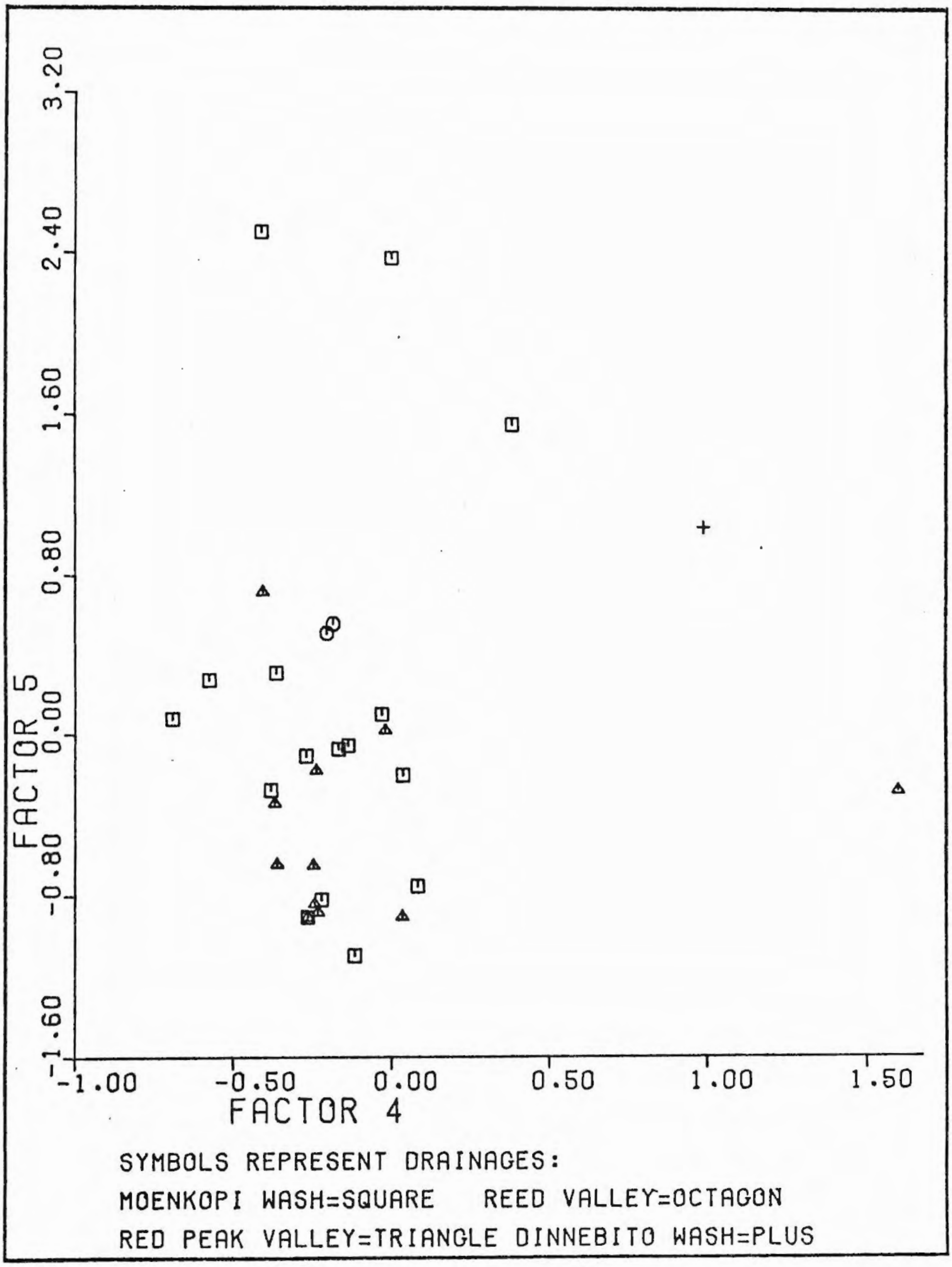


Figure 36. Factor scores for Factors 4 and 5, time period I.

two different factors. The only site with vitreous wood was D:7:236, an undated site located in Moenkopi Wash. The factor with fracture-line chert had significant factor scores at two sites, both of which date to A.D. 793. They are, however, at opposite ends of the study area (D:7:265 is in Moenkopi Wash; D:11:1162 is in Red Peak Valley). It should be recalled that although it has not been found in outcrop locally, this material does derive from a formation, the Dakota Sandstone, that occurs locally.

Attention should be called, at this point, to the inversions in the first five factors (see Table 14); all of them involve white baked siltstone, even though it is significant only in Factor 5. Recall that white baked siltstone usually is a good indicator of Basketmaker II sites. Although all 31 sites used in this analysis are from the early end of the temporal sequence, a time span as great as 2,000 years is represented among them. It is difficult to assess the time range represented by the sites classified as A.D. 793 as opposed to those assigned no date at all. However, it should be pointed out that the only significant factor scores for the first three factors (which together have the majority of nonlocal materials) and the only site with vitreous petrified wood are among the sites dated to A.D. 793 (see Appendix E). Factors 4 and 5 derive principally from local materials, and all but one (five out of six) of the sites with significant scores are in the undated group. It thus appears that some of the patterning detected by this factor analysis is temporal. Dating control is much tighter for the next two groups of sites; thus, spatial patterns should be more readily identifiable.

Factor Analysis for Time Period II (A.D. 800-999)

The factor analysis for the second temporal group (28 sites) employed 26 variables of the potential 28 (see Table 12). Yellow baked siltstone and obsidian were deleted from the analysis because they are not present at any of the sites. The correlation matrix for raw materials at sites dating to this time period has relatively fewer high correlations (see Table 15). Correlations are between quartzite and creamy opaque (.753), quartzite and pink chert (.655), siderite and oolitic chert (.693), pink chert and creamy opaque (.665), and basalt and vitreous petrified wood (.533). These combinations are between local and distant, local and intermediate, intermediate and distant, and two distant materials; there are no high correlations between local materials. Nonlocal combinations are between materials potentially available in the same direction (pink chert and creamy opaque to the northeast; basalt and vitreous petrified wood to the south). Interestingly, none of these material correlations appeared in the analysis for the early sites. The early site correlations were between locally available materials and between local and intermediate materials. During this midrange time period, there evidently was more diversity in the raw material sources used and less focus on local materials.

Eleven of the 26 factors have eigenvalues greater than 1.00 (see Table 16). These 11 factors explain 79% of the original variance, which also is within the acceptable range. The five significant correlations noted in the correlation matrix above contribute to the makeup of

Table 15. Simplified[a] Correlation Coefficient Matrix for A.D. 800-999 Sites Factor Analysis.

Raw Material	Raw Material					
	Local Petri-fied Wood	Vein Quartz	Quartz-ite	Si-der-ite	Iron Con-cre-tions	Gray Baked Silt-stone
Local petrified wood						
Vein quartz						
Quartzite						
Siderite						
Iron concretions			.426			
Gray baked silt-stone						
Red, white, and blue Navajo chert						
Owl Rock chert.........						-.431
Chalcedony	.389					
Basalt						
Pink chert			.655			
Fracture-line chert ...		.404				
Creamy opaque		.433	.753			
Vitreous petrified wood	.421					
Oolitic chert				.693		
Brown chert gravel						

Table 15 (Continued)

Raw Material	Raw Material				
	Red, White, & Blue Navajo Chert	Owl Rock Chert	Chal-ce-dony	Basalt	Pink Chert
Local petrified wood					
Vein quartz					
Quartzite					
Siderite					
Iron concretions					
Gray baked silt-stone					
Red, white, and blue Navajo chert					
Owl Rock chert	.410				
Chalcedony					
Basalt					
Pink chert					
Fracture-line chert					
Creamy opaque			.427		.665
Vitreous petrified wood				.533	
Oolitic chert					
Brown chert gravel				.387	

[a]Coefficients not significant at the .05 level (.3746 or greater) have been omitted.

Table 16. List of Variables Arranged According to a Descending Order of Factor Loadings: Factors 1-11 for A.D. 800-999 Sites.

Factor 1		Factor 2		Factor 3		Factor 4	
Material Code	Loading	Material Code	Loading	Material Code	Loading	Material Code	Loading
				Factor Loadings			
58	.893*	50	.791*	53	.799*	18	.911*
9	.861*	55	.725*	1	.574*	60	.860*
28	.852*	7	.553*	7	.545*	13	.290
1	.411	5	.266	63	.541*	73	.140
5	.379	29	.260	4	.454	63	.090
50	.284	71	.232	35	.148	37	.068
29	.113	30	.232	28	.093	45	.032
30	.037	73	.174	55	.083	7	.021
71	.014	9	.168	18	.069	40	.018
63	.007	4	.127	73	.055	5	.007
57	.004	53	.121	23	.043	59	.004
72	-.005	37	.113	37	.036	58	-.007
60	-.019	57	.089	58	.025	50	-.022
45	-.040	58	.070	30	.014	4	-.027
40	-.052	1	.067	40	-.036	9	-.028
18	-.072	23	.053	57	-.038	29	-.039
53	-.084	45	.008	50	-.047	23	-.051
23	-.087	59	-.038	59	-.068	53	-.060
37	-.091	60	-.053	71	-.070	57	-.066
59	-.094	28	-.105	72	-.082	28	-.087
7	-.099	18	-.130	60	-.111	72	-.114
13	-.158	35	-.148	13	-.171	1	-.119
35	-.166	72	-.157	45	-.174	30	-.119
73	-.183	40	-.188	9	-.201	55	-.132
4	-.219	63	-.192	5	-.213	71	-.193
55	-.253	13	-.494	29	-.328	35	-.272
				Eigenvalue			
	3.462		2.673		2.176		2.096
				Cumulative Proportion of Total Variance			
	.133		.236		.320		.400

Table 16 (Continued)

Factor 5		Factor 6		Factor 7		Factor 8	
Material Code	Loading	Material Code	Loading	Material Code	Loading	Material Code	Loading
			Factor Loadings				
40	.750*	57	.821*	37	.815*	45	.817*
35	.580*	5	.609*	30	.265	73	.675*
45	.188	55	.309	35	.259	63	.395
60	.159	28	.261	45	.194	28	.176
1	.139	4	.192	28	.185	57	.165
53	.139	1	.172	13	.180	35	.150
71	.117	45	.164	60	.161	50	.146
30	.088	23	.137	71	.152	7	.085
5	.071	63	.054	55	.139	60	.066
37	.068	58	.041	7	.124	59	.064
4	.044	30	.014	59	.102	37	.055
59	.029	37	.000	23	.029	18	.051
58	-.012	18	-.016	50	.021	1	.036
9	-.014	71	-.030	57	.018	72	-.027
55	-.018	60	-.031	63	-.005	23	-.031
23	-.024	50	-.042	53	-.017	40	-.054
29	-.033	59	-.089	9	-.040	71	-.070
7	-.055	72	-.114	18	-.095	13	-.074
50	-.056	53	-.122	72	-.120	9	-.131
57	-.076	40	-.129	58	-.130	1	-.136
28	-.092	13	-.151	1	-.135	58	-.147
18	-.094	9	-.199	40	-.151	30	-.164
13	-.153	35	-.205	29	-.186	29	-.174
63	-.193	73	-.210	5	-.233	53	-.216
73	-.253	7	-.234	73	-.430	5	-.217
72	-.813*	29	-.438	4	-.579*	55	-.226
			Eigenvalue				
	1.826		1.797		1.581		1.452
			Cumulative Proportion of Total Variance				
	.470		.540		.600		.656

Table 16 (Continued)

Factor 9		Factor 10		Factor 11	
Material Code	Loading	Material Code	Loading	Material Code	Loading
		Factor Loadings			
30	.741*	23	.859*	59	.827*
29	.356	29	.434	1	.381
4	.347	57	.365	13	.195
1	.187	63	.166	60	.172
9	.169	28	.068	45	.108
35	.165	9	.060	37	.101
57	.144	7	.047	58	.089
50	.109	55	.046	50	.068
53	.105	45	.006	4	.066
37	.104	50	-.001	55	.023
59	.046	53	-.003	23	-.019
60	.041	60	-.009	40	-.027
13	.013	59	-.038	73	-.052
55	.009	37	-.051	53	-.082
18	.005	18	-.052	28	-.084
45	-.033	71	-.052	7	-.087
28	-.034	1	-.076	57	-.088
73	-.054	30	-.138	5	-.106
23	-.071	13	-.158	30	-.111
5	-.085	72	-.164	72	-.150
58	-.089	58	-.165	9	-.159
72	-.115	73	-.183	29	-.173
63	-.127	5	-.224	18	-.174
7	-.287	35	-.227	71	-.215
40	-.407	40	-.242	63	-.284
71	-.654*	4	-.287	35	-.366
		Eigenvalue			
	1.312		1.248		1.025
		Cumulative Proportion of Total Variance			
	.707		.755		.794

Factors 1, 3, and 4. Factor loadings greater than .5000 will be highlighted below.

Creamy opaque, pink chert, and quartzite all contribute significantly to Factor 1. Both of the nonlocal materials are available to the northeast. The quartzite could have been procured there as well, but its association with these two materials also may reflect technology in that it primarily is a hammerstone material.

Gray and brown chert gravels and basalt all have high loadings on Factor 2. Sources for all three of these material classes have not been pinpointed but it is possible to obtain all three from the south, in the direction of the San Francisco volcanic field. The scattergram for Factors 1 and 2 (see Figure 37) indicates that most Moenkopi Wash sites have positive scores for Factor 2, but are widely varied with regard to Factor 1. With the exception of D:11:569, which has the highest score for Factor 2, all Reed Valley sites have negative or extremely low scores on both of these factors. Red Peak Valley sites have negative scores on Factor 1 (with the exception of D:11:1084, which has a moderate positive score) but are divided on Factor 2. The single Dinnebito Wash site, D:11:288, has negative scores for both factors.

Basalt also figures prominently in Factor 3, where it is associated with vitreous petrified wood, chalcedony, and Chinle chert, three other nonlocal materials available to the south. The scattergram (Figure 38) indicates varied scores for Moenkopi Wash sites on Factor 3. The other three drainages have more restricted and overlapping ranges of variation with a single Reed Valley outlier (D:11:478).

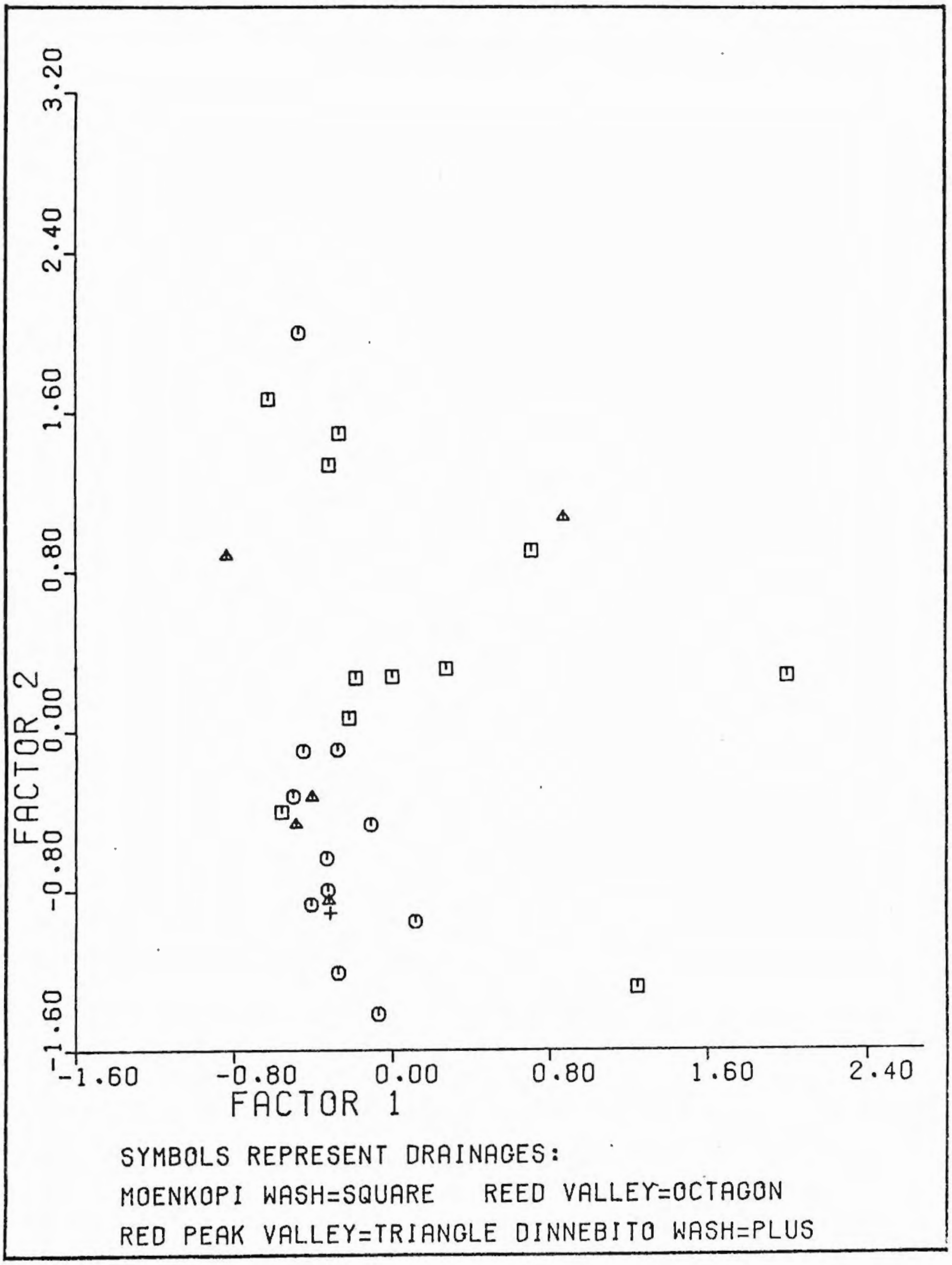


Figure 37. Factor scores for Factors 1 and 2, time period II.

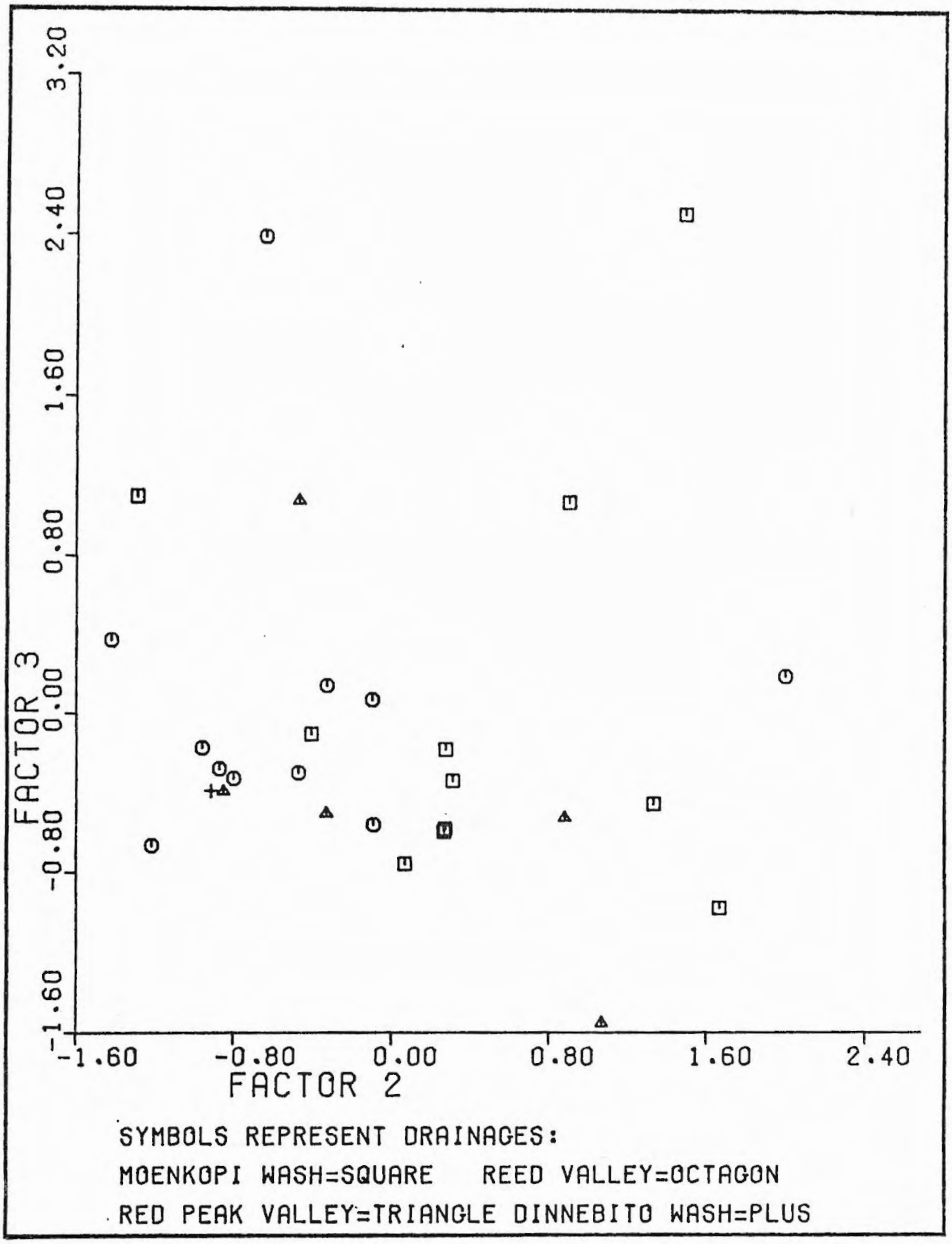


Figure 38. Factor scores for Factors 2 and 3, time period II.

Siderite and oolitic chert have high loadings on Factor 4, but they occur together at only one site, D:11:623. D:11:623 is a Reed Valley site, but the remainder of the Reed Valley sites, as well as most of the rest of the sites, are clustered on the low side of zero for this factor. The two other sites with these materials are from Red Peak Valley (D:11:707) and Moenkopi Wash (D:7:234), so there does not appear to be spatial patterning for this factor (see Figure 39). Owl Rock chert and red, white, and blue Navajo chert, two intermediate materials, are negatively associated with gray baked siltstone in Factor 5. The distribution of sites appears to be fairly evenly divided on Factor 5 (see Figure 40).

Material associations in the remaining six factors generally are not as meaningful as those in most of the preceding five factors, which explain almost half the original variance. The association of fracture-line chert with vein quartz, for example, in Factor 6 occurs at only one site, D:7:213, and does not have much significance beyond the possibility that both could have been procured to the northeast and/or that the latter served as hammerstone material in the manufacture of the former. The fact that fracture-line chert again was not included with the other materials available to the northeast in Factor 1 suggests that it was procured separately, either through other contacts, also in the northeast, or that the search for local sources of this material should be intensified. Moenkopi Wash sites are the only ones with significant positive scores on Factor 6 (see Figure 41).

White Navajo chert is inversely associated with local petrified wood in Factor 7, again not an immediately meaningful combination beyond

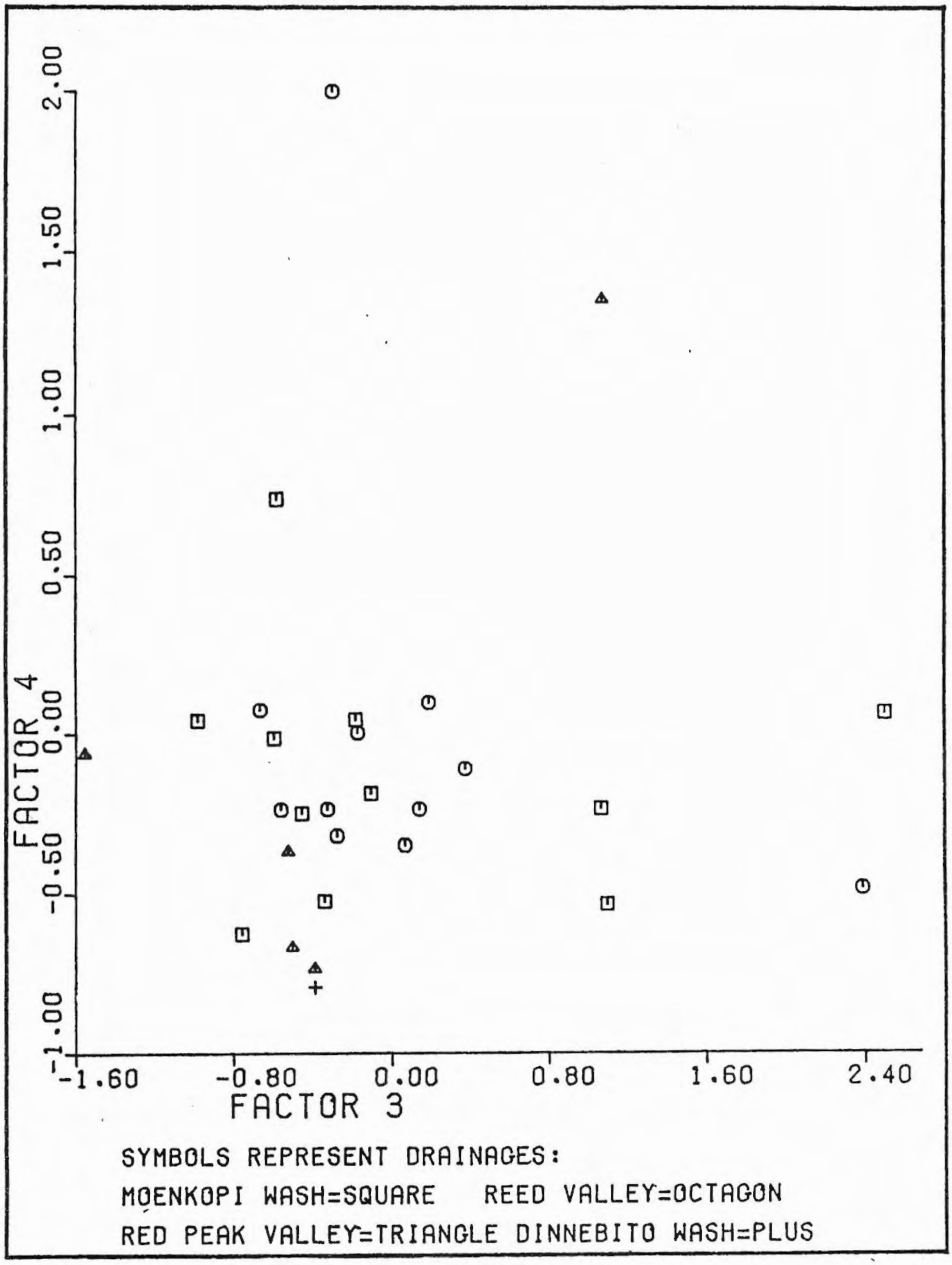


Figure 39. Factor scores for Factors 3 and 4, time period II.

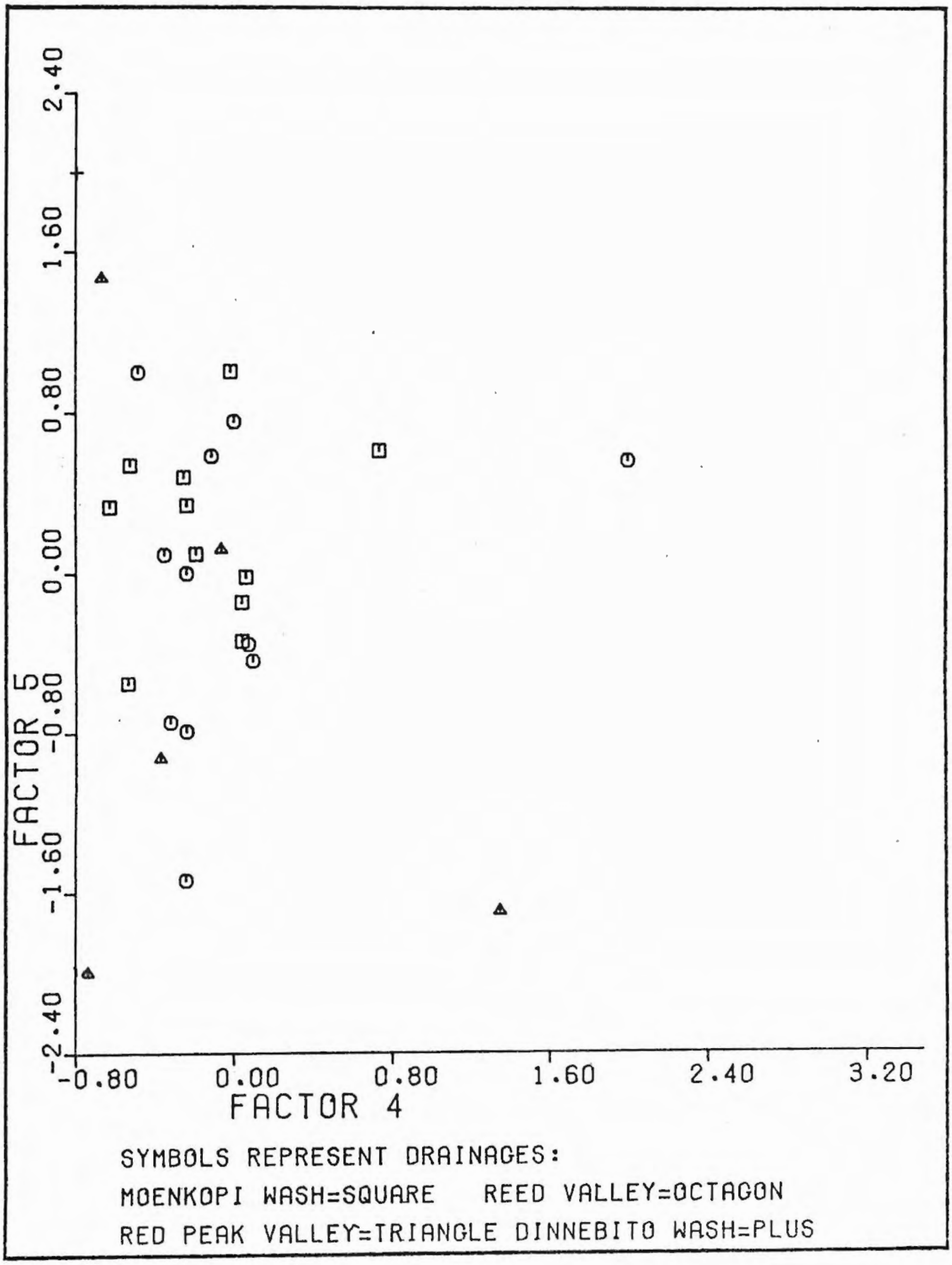


Figure 40. Factor scores for Factors 4 and 5, time period II.

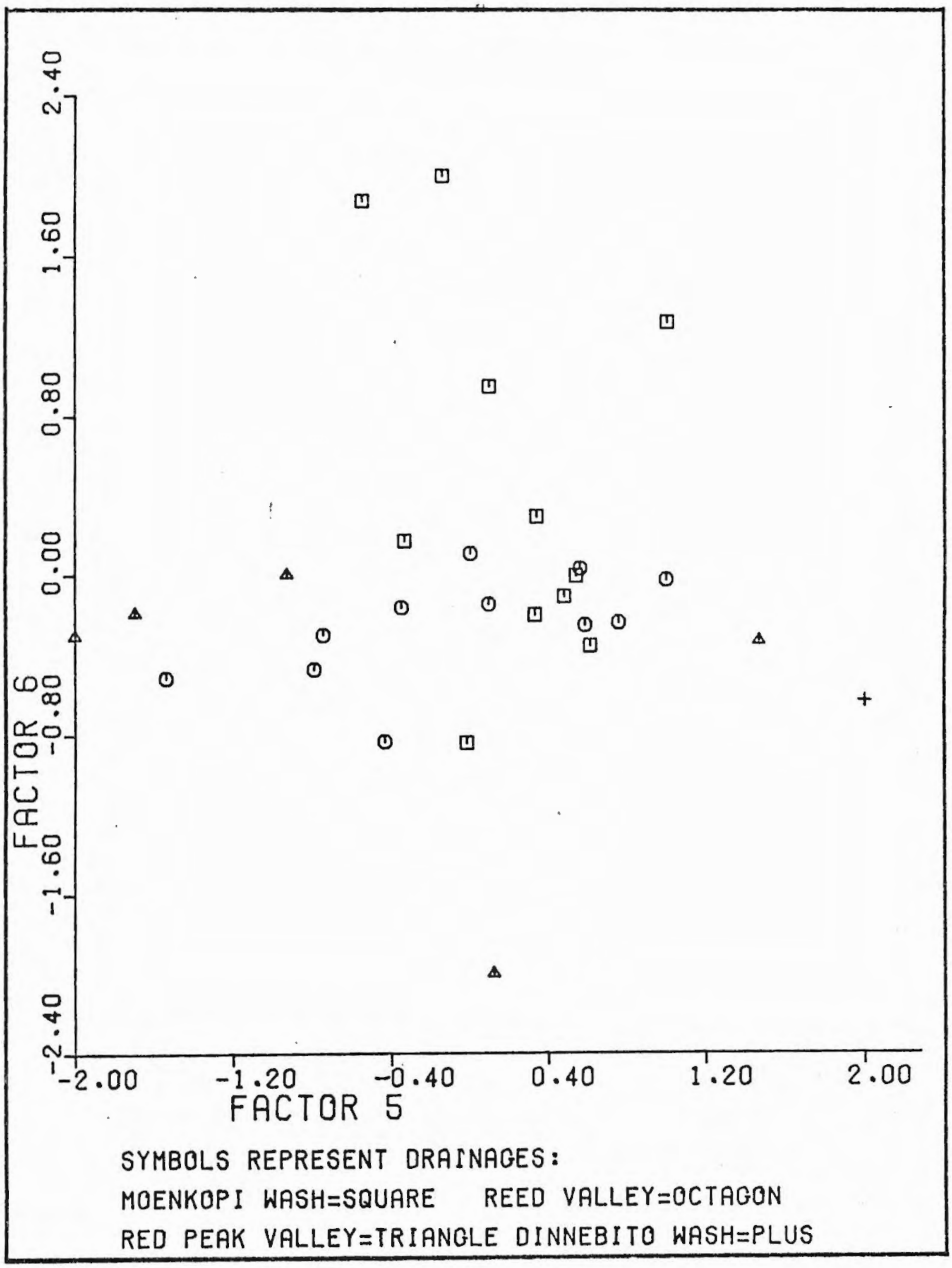


Figure 41. Factor scores for Factors 5 and 6, time period II.

the apparent nonuse of the latter as hammerstone material in the manufacture of the former. Only Moenkopi Wash and Reed Valley sites have significant positive scores on this factor (see Figure 42). Sources for coarse-grained petrified wood have been located in Dinnebito Wash and Red Peak Valley, which may explain the negative scores for those sites on this factor. In Factor 8, purple-white chalcedony/chert is associated with pink baked siltstone. Although the majority of sites from all drainages have negative scores on this factor (see Figure 43), almost all of the drainages are represented on the positive side of the graph as well. Brown Navajo chert is negatively associated with white baked siltstone in Factor 9. Single materials have high loadings on Factors 10 and 11, baked sandstone and quartzitic chert, respectively. The drainages do not show strong spatial patterning with the last three factors either (see Figures 44-45). Because quartzitic chert is present at only three sites, two in Reed Valley and one in Moenkopi Wash, the factor scores mean little and the scattergram is not presented.

It is possible that the materials from sources that have not been pinpointed, i.e., the gravels and basalt, actually were procured in directions that differed from those of materials with which the factor analysis combined them, but there presently is no reason to believe that was the case. Material combinations with known sources conform to expectation, which predicted that they should have been procured from the same direction. Further, expectations are that sites that have high factor scores on factors with materials in one direction should not have high scores on factors with materials available in a different direction. Factor scores for the 28 sites were examined to this end.

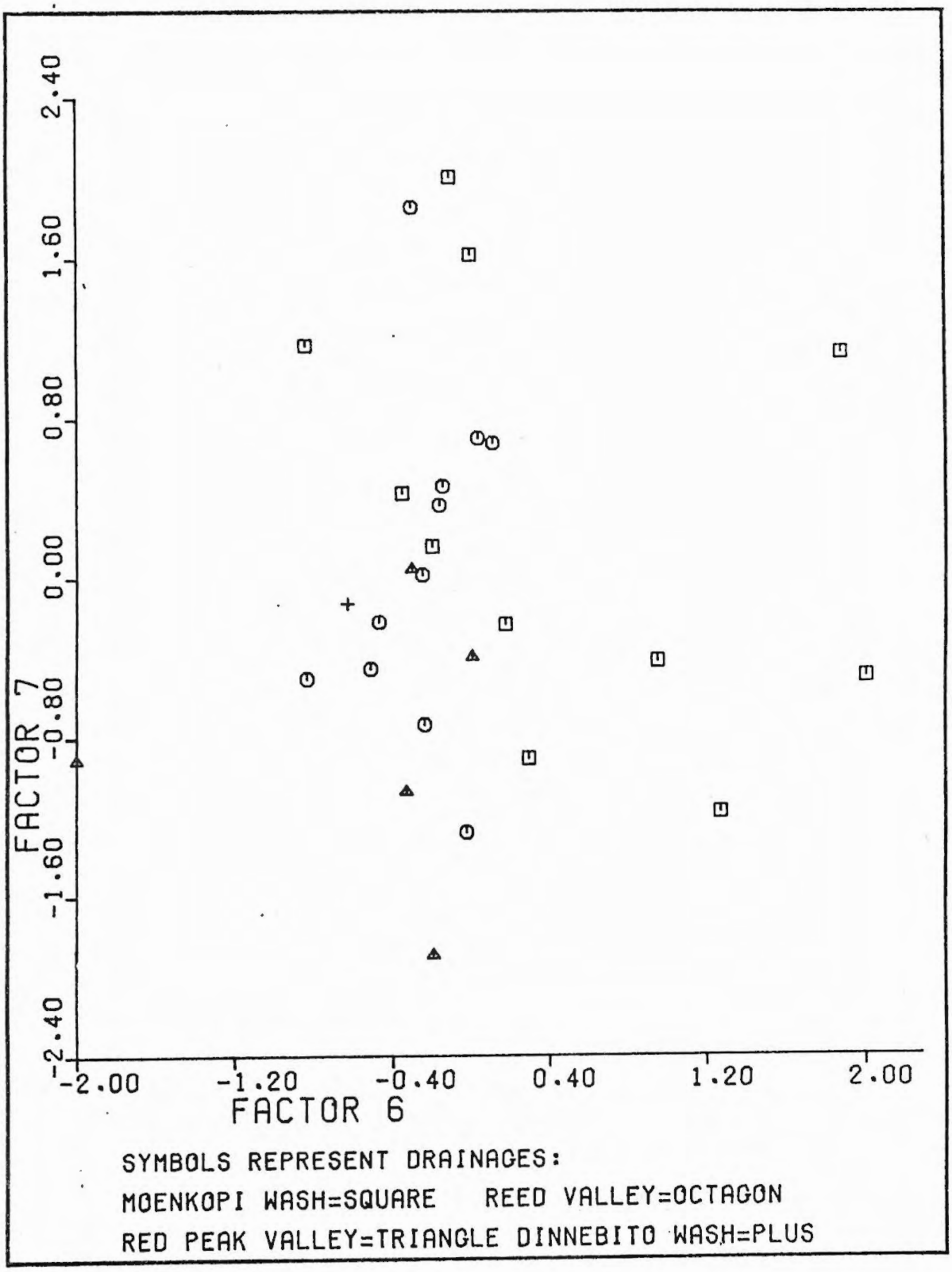


Figure 42. Factor scores for Factors 6 and 7, time period II.

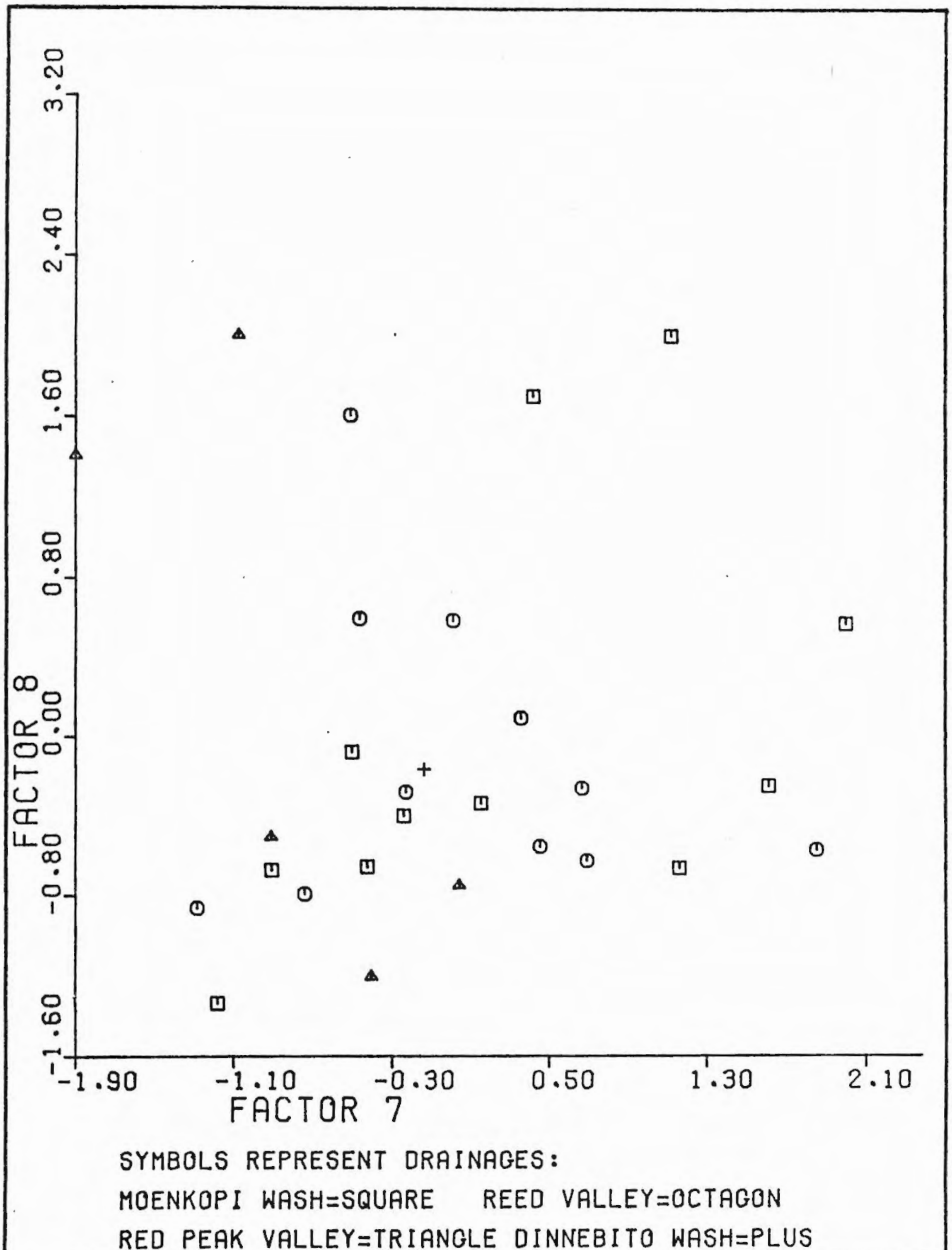


Figure 43. Factor scores for Factors 7 and 8, time period II.

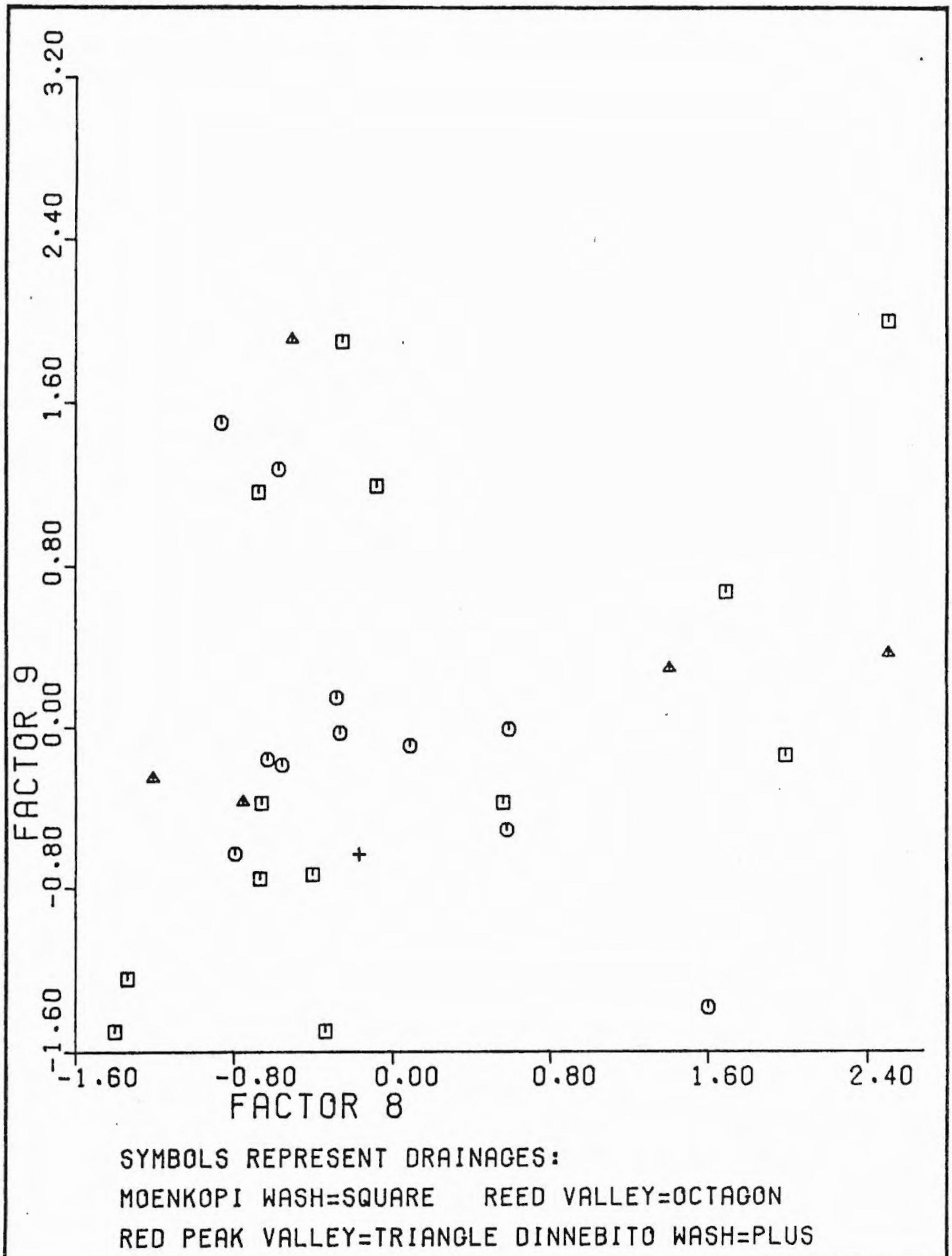


Figure 44. Factor scores for Factors 8 and 9, time period II.

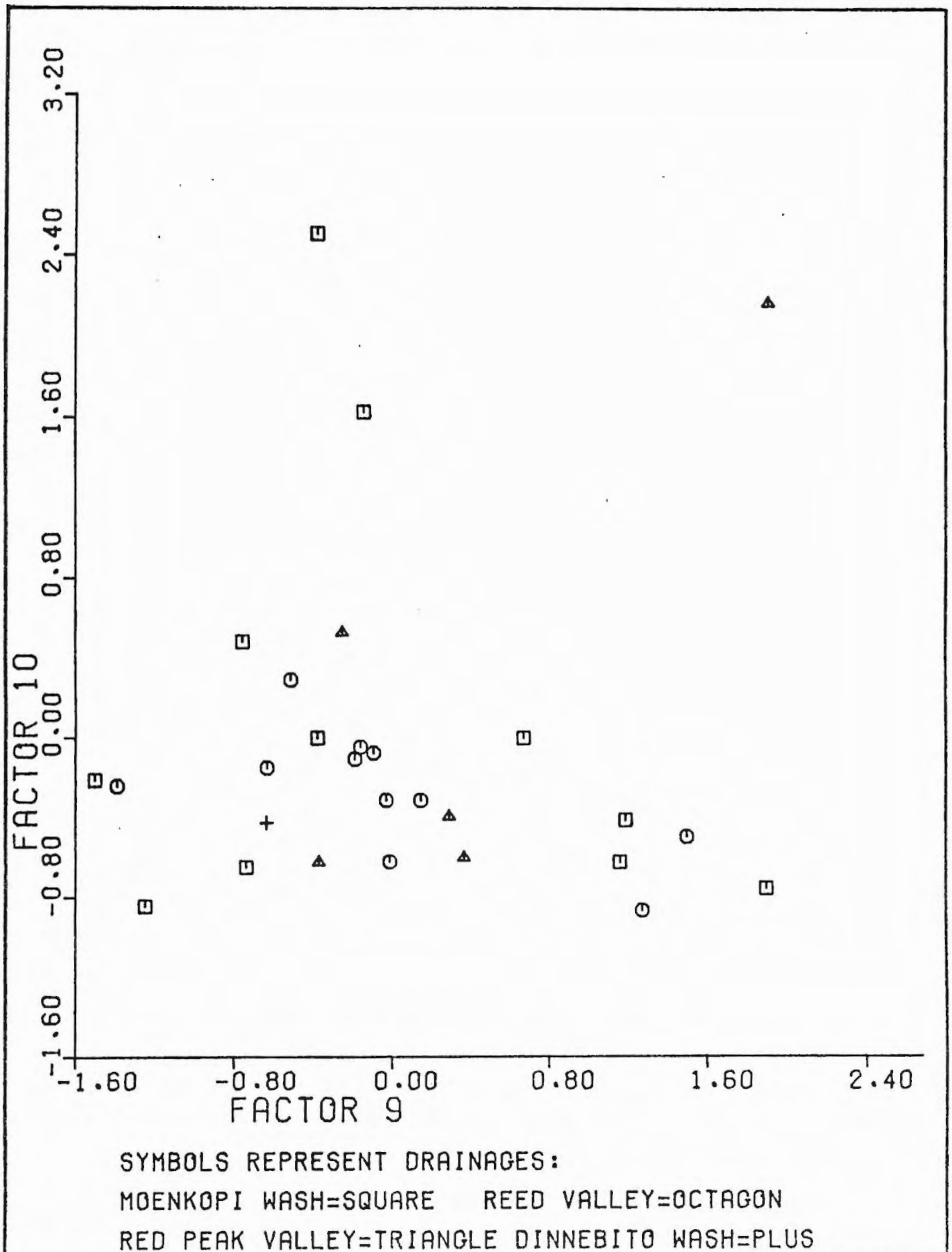


Figure 45. Factor scores for Factors 9 and 10, time period II.

Only Factors 1, 2, 3, and 6 have distant imports, so only the scores from them were employed in this part of the analysis.

Thirteen of the 28 (46%) sites have factor scores with absolute values greater than 1.00 on at least one of these four factors (see Appendix E). Nine of the 13 have scores greater than 1.00 on only a single factor, so they are dropped from consideration. Two sites have high scores on two factors. Of these, D:7:262 has high positive scores on two factors, both with materials available to the south, and D:7:213 has high scores on factors with materials from opposite directions, which conflicts with expectations. Both of these are Moenkopi Wash sites. Two sites have high scores on more than two factors. One, D:11:1084, has a positive score on Factor 2 with materials available to the south, a negative score on Factor 3 with materials also available to the south, and an even higher negative score on Factor 6 with materials available to the northeast. This outcome does not conflict with expectations because it reflects the presence of Factor 2 materials (gray and brown chert gravels and basalt) and the absence of materials in Factor 3 (basalt, vitreous petrified wood, chalcedony, and Chinle chert) and Factor 6 (fracture-line chert and vein quartz). Examination of the raw data for this site (see Appendix C) eliminates the confusion because this complicated pattern merely reflects the presence of gray chert gravel, an intermediate material, at the site. The last site (D:7:264) does not conform to expectations, as it has positive scores on Factors 1 (NE), 3 (S), and 6 (NE) and a negative score on Factor 2 (SW). Inspection of the raw data for this site (see Appendix C) confirms this discrepancy because the site has pink chert, fracture-line chert, and

Chinle chert. The only mediating factor is the site's location, the Moenkopi Wash area, supposedly the area in which exchange ties developed the earliest. This does not, however, change the fact that the outcome did not conform to expectations. Only two sites of the total 28 had scores that conflicted with the proposed model, and both of them are located in the Moenkopi Wash area. Although the model was not supported 100% and there are vagaries concerning the sourcing of basalt and the gravels, the predicted trend does appear to hold true. During the next period this trend for separateness of exchange ties should break down altogether in favor of increased interaction.

Factor Analysis for Time Period III (A.D. 1000-1150)

The factor analysis for the latest time period (with 38 sites) also employed 26 of the 28 variables (see Table 12). Vein quartz and quartzitic chert were omitted from the analysis because they do not occur at sites of this time period. The correlation matrix (Table 17) for this period had the following combinations significant at the .01 ($r > .4432$) level: gray baked siltstone and pink chert (.720), local petrified wood and gray chert gravel (.668), yellow baked siltstone and gray chert gravel (.550), brown Navajo chert and obsidian (.532), iron concretions and pink baked siltstone (.525), iron concretions and basalt (.511), baked sandstone and basalt (.510), baked sandstone and iron conretions (.482), and local petrified wood and yellow baked siltstone (.455). These combinations are between local materials, local and intermediate, local and distant, and intermediate and distant materials. Although there are more significant correlation coefficients during this

Table 17. Simplified[a] Correlation Coefficient Matrix for A.D. 1000-1150 Sites Factor Analysis.

Raw Material	Raw Material: Local Petrified Wood	Siderite	Baked Sandstone	Iron Concretions	Gray Baked Siltstone
Local petrified wood					
Siderite					
Baked sandstone					
Iron concretions			.482		
Gray baked siltstone					
Pink baked siltstone				.525	
Yellow baked siltstone ...	.455				
Brown Navajo chert					
White Navajo chert					
Chalcedony		.442			
Obsidian					
Basalt			.510	.511	
Pink chert					.720
Gray chert gravel	.668				
Brown chert gravel		.393			
Vitreous petrified wood ..					
Oolitic chert					

Table 17 (Continued)

Raw Material	Raw Material			
	Pink Baked Silt-stone	Yellow Baked Silt-stone	Brown Navajo Chert	White Navajo Chert
Local petrified wood				
Siderite				
Baked sandstone				
Iron concretions				
Gray baked siltstone				
Pink baked siltstone				
Yellow baked siltstone				
Brown Navajo chert				
White Navajo chert			.356	
Chalcedony				
Obsidian			.532	.346
Basalt				
Pink chert				
Gray chert gravel		.550		
Brown chert gravel				
Vitreous petrified wood		.368		
Oolitic chert			.372	

[a]Coefficients not significant at the .05 level (.3444 or greater) have been omitted.

period, there are fewer at the high levels; the correlations are not as strong. Fewer consistent combinations of materials (high correlations) are expected if raw materials were exchanged freely as has been suggested for this time period.

Ten of the 28 factors have eigenvalues greater than 1.00 (see Table 18). These 10 factors explain 73% of the original variance, which is within, but at the low end of, the acceptable range. This low percentage of variance explained also is an indication of the greater diversity in the assemblages because the data are not summarized easily by only a few factors. The nine significant correlations noted above contribute to the makeup of Factors 1, 2, 3, and 5. Factor loadings greater than .5000 will be discussed below (see Table 18).

Iron concretions, baked sandstone, and basalt have high positive loadings on Factor 1. Reasons for this association are not immediately obvious, with the possible exception of the use of baked sandstone in the manufacture of basalt implements. Gray chert gravel, local petrified wood, and yellow baked siltstone all figure prominently in the makeup of Factor 2. Again, an imported material is combined with a locally available hammerstone material and an additional local material. The scattergram (Figure 46) does not indicate any spatial associations for these two factors. The majority of sites have low negative values for Factor 1 and are divided on Factor 2. The three extreme outliers on the positive side are Moenkopi Wash sites, but Reed Valley and Red Peak Valley each has an outlier as well. All of the Dinnebito Wash sites are on the negative side for both factors.

Table 18. List of Variables Arranged According to a Descending Order of Factor Loadings: Factors 1-10 for A.D. 1000-1150 Sites.

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Material Code	Loading	Material Code	Loading	Material Code	Loading	Material Code	Loading	Material Code	Loading
				Factor Loadings					
29	.855*	50	.883*	72	.919*	18	.834*	6	.874*
23	.799*	4	.839*	28	.899*	1	.752*	30	.772*
7	.709*	74	.735*	7	.142	55	.292	37	.542*
73	.487	63	.286	1	.098	35	.283	57	.197
6	.191	55	.140	73	.088	71	.189	7	.176
72	.112	53	.077	4	.058	9	.169	35	.094
28	.049	29	.075	23	.054	63	.102	71	.050
4	.037	60	.065	71	.047	50	.070	60	.066
50	.027	58	.056	74	.015	28	.049	58	.043
1	.023	45	.044	37	.009	7	.046	55	.031
57	-.027	18	.032	60	-.005	60	.028	63	.019
9	-.033	7	.012	6	-.006	6	.014	28	.001
58	-.033	57	.008	29	-.012	23	.001	4	-.015
60	-.033	28	-.004	9	-.023	74	-.009	13	-.030
71	-.073	30	-.005	63	-.054	72	-.075	1	-.040
74	-.080	72	-.040	58	-.061	73	-.087	53	-.049
18	-.092	23	-.060	53	-.061	29	-.089	23	-.053
53	-.100	6	-.085	35	-.082	40	-.121	50	-.053
35	-.105	71	-.104	50	-.084	58	-.124	29	-.061
55	-.123	1	-.107	57	-.086	53	-.130	9	-.066
30	-.157	73	-.119	30	-.109	30	-.133	72	-.088
13	-.158	35	-.130	18	-.114	4	-.176	74	-.096
63	-.216	9	-.166	55	-.143	13	-.204	73	-.117
37	-.231	37	-.179	13	-.145	57	-.216	40	-.128
40	-.277	13	-.211	45	-.201	37	-.256	18	-.135
45	-.301	40	-.245	40	-.403	45	-.375	45	-.219
				Eigenvalue					
	2.952		2.269		2.269		1.932		1.855
				Cumulative Proportion of Total Variance					
	.114		.300		.300		.394		.445

Table 18 (Continued)

Factor 6		Factor 7		Factor 8		Factor 9		Factor 10	
Material Code	Loading	Material Code	Loading	Material Code	Loading	Material Code	Loading	Material Code	Loading
				Factor Loadings					
58	.759*	53	.837*	60	.807*	9	.721*	13	.841*
63	.611*	71	.586*	30	.410	57	.716*	71	.155
73	.457	74	.330	40	.362	73	.347	6	.106
9	.206	35	.100	9	.275	55	.198	7	.084
37	.185	30	.084	1	.218	53	.172	9	.080
74	.180	18	.083	4	.150	45	.169	23	.058
29	.082	73	.078	23	.076	74	.113	58	.052
72	.075	13	.053	28	.034	60	.111	55	.022
40	.033	58	.041	72	-.002	6	.088	28	.019
50	.027	72	.009	74	-.003	30	.070	50	.007
4	.025	57	.002	63	-.009	35	.067	63	-.018
6	.005	28	.001	53	-.031	18	.063	60	-.034
1	-.012	40	-.014	7	-.040	29	.024	4	-.040
13	-.023	23	-.019	29	-.043	72	.010	57	-.059
30	-.027	6	-.026	6	-.074	13	.006	74	-.062
53	-.054	29	-.041	73	-.084	58	-.002	18	-.080
23	-.075	9	-.046	50	-.089	7	-.012	53	-.081
71	-.095	7	-.086	71	-.100	63	-.043	72	-.108
18	-.117	60	-.093	58	-.108	50	-.048	30	-.153
28	-.124	50	-.096	57	-.122	23	-.068	29	-.155
7	-.133	1	-.161	13	-.150	28	-.099	1	-.163
60	-.158	4	-.182	18	-.221	1	-.112	45	-.255
57	-.240	45	-.200	37	-.243	37	-.132	73	-.279
35	-.317	37	-.208	35	-.251	4	-.165	40	-.393
45	-.324	63	-.314	45	-.366	71	-.245	37	-.416
55	-.333	55	-.470	55	-.405	40	-.353	35	-.455
				Eigenvalue					
	1.611		1.563		1.460		1.384		1.317
				Cumulative Proportion of Total Variance					
	.507		.567		.623		.677		.727

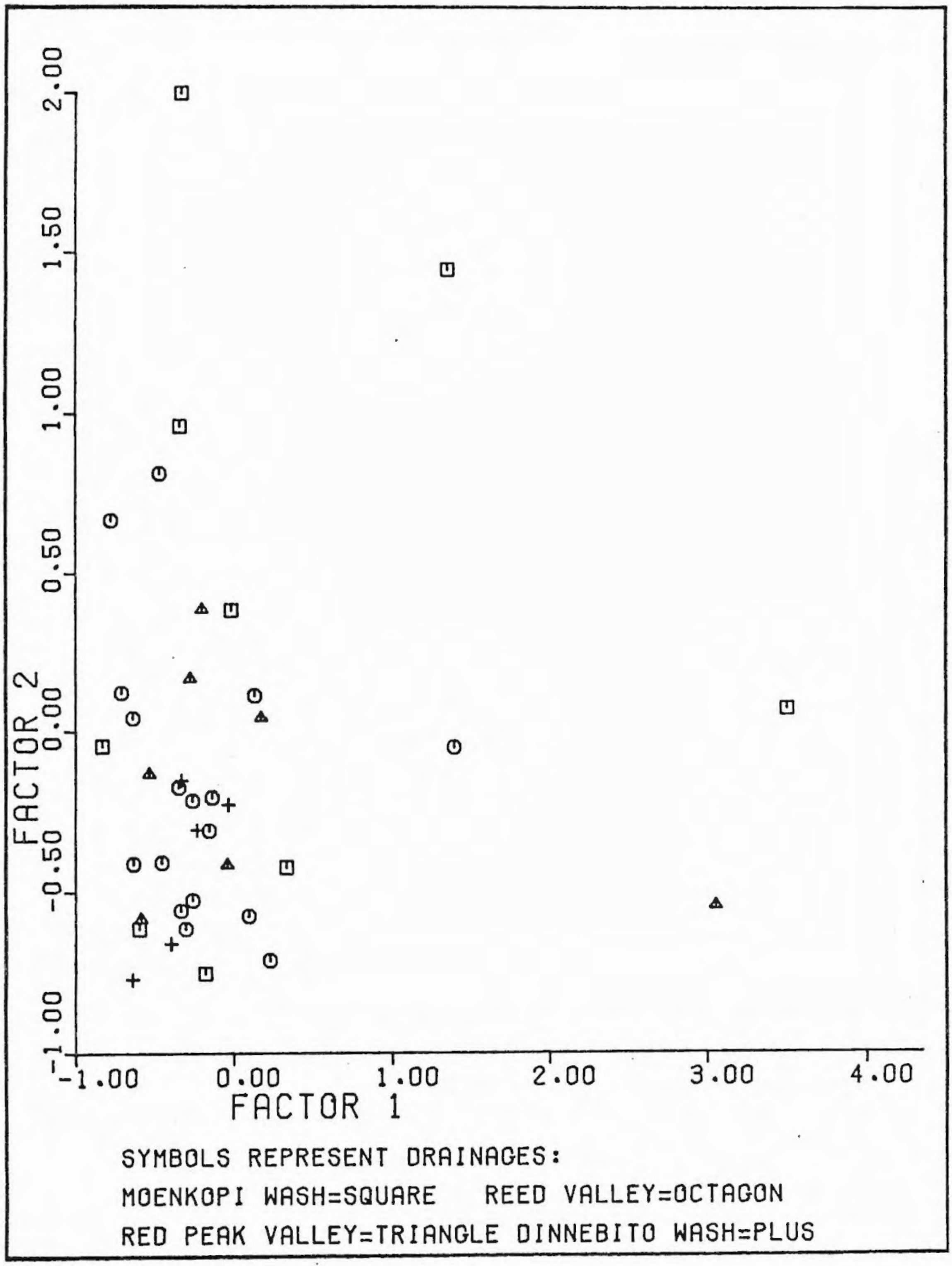


Figure 46. Factor scores for Factors 1 and 2, time period III.

Gray baked siltstone and pink chert are important in Factor 3; their association has no immediate meaning. Moenkopi Wash sites again are the positive outliers, but other spatial patterning again is absent (see Figure 47).

Siderite and chalcedony, also an association with no obvious meaning, have high positive loadings on Factor 4. The scattergram (Figure 48) indicates no clear-cut spatial patterning here either, except that most Reed Valley sites have negative scores on both Factors 3 and 4.

Obsidian, brown Navajo chert, and white Navajo chert all have high positive loadings on Factor 5. Brown and white Navajo chert are from the same formation, but usually from different outcrops, so their association is not surprising. More outcrops of Navajo chert have been found to the west and south of Black Mesa, than have been found to the north, so the association with obsidian also is not a surprise. The scattergram (Figure 49) indicates that the sites with significant scores on Factor 5 are from Dinnebito Wash, Red Peak Valley, and Reed Valley, not Moenkopi Wash, which is unusual. Most of the sites have scores that are negative and not significant.

Creamy opaque and Chinle chert have significant positive loadings on Factor 6. The association of these materials, the former from the northeast and the latter from the south, supports the model of proposed interaction among Black Mesa sites during the later time periods. As mentioned earlier, it is assumed that some form of increased interaction, whether through trade or communication, among Black Mesa sites, would have led to the combination on sites of materials with

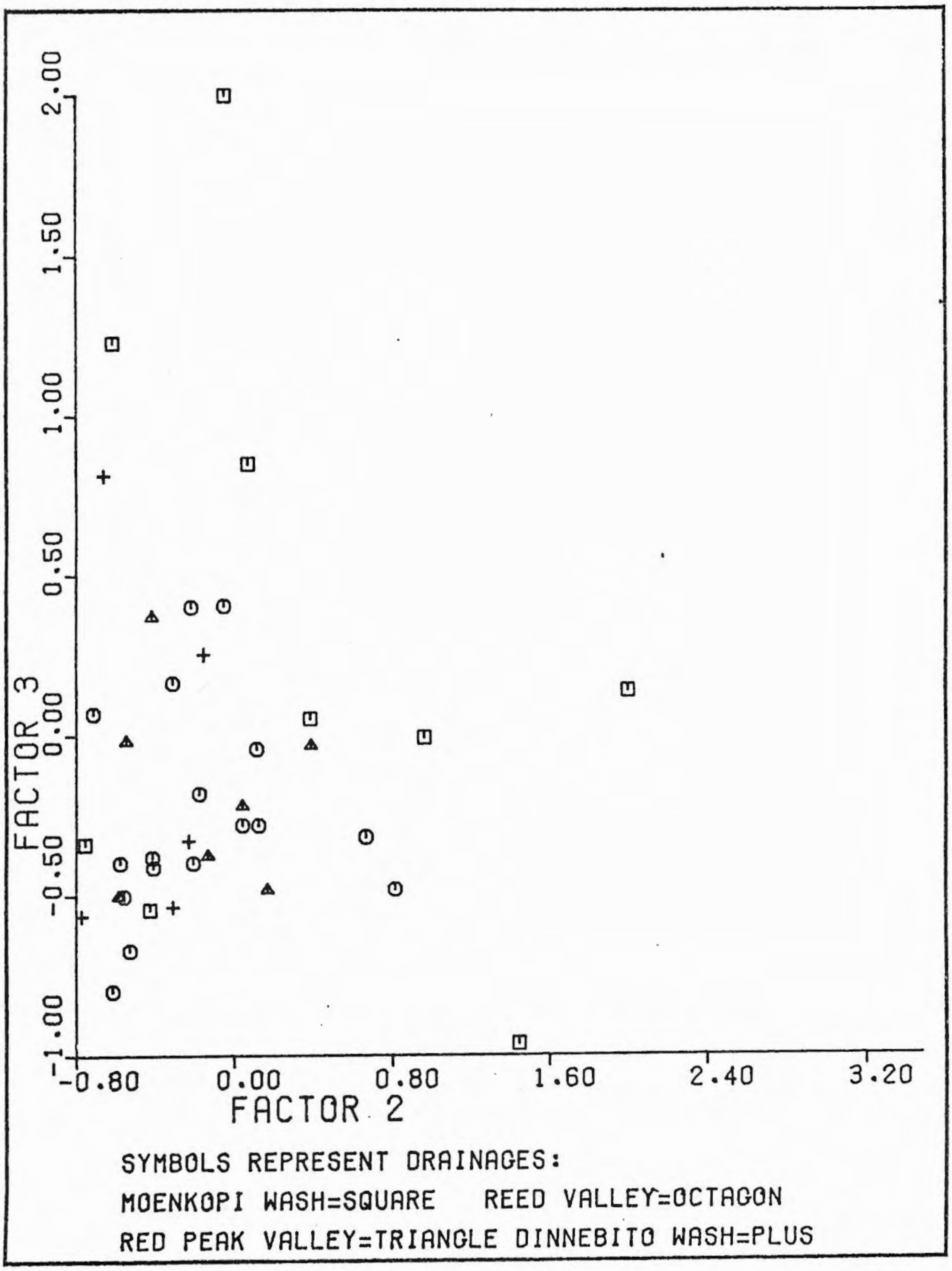


Figure 47. Factor scores for Factors 2 and 3, time period III.

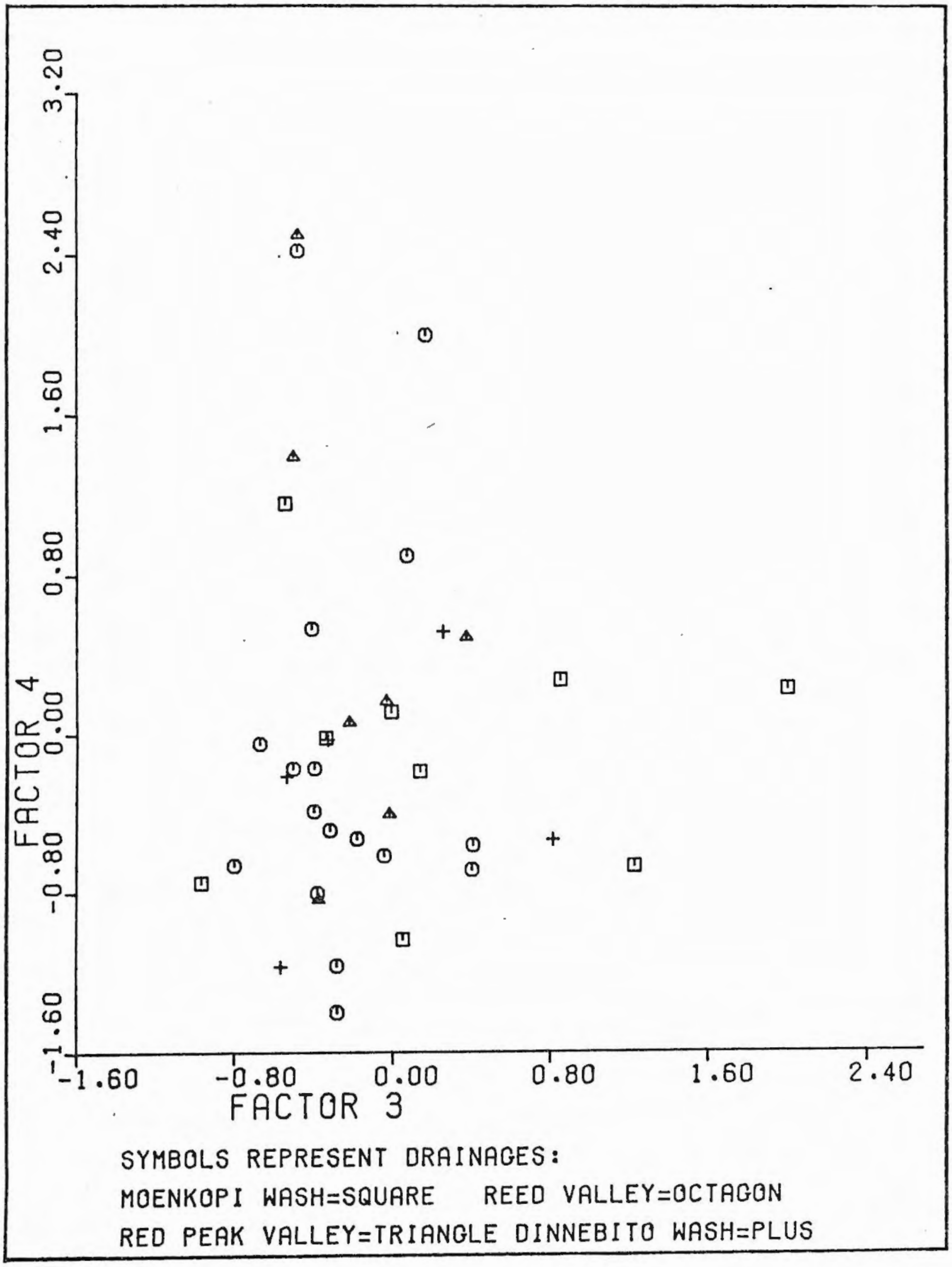


Figure 48. Factor scores for Factors 3 and 4, time period III.

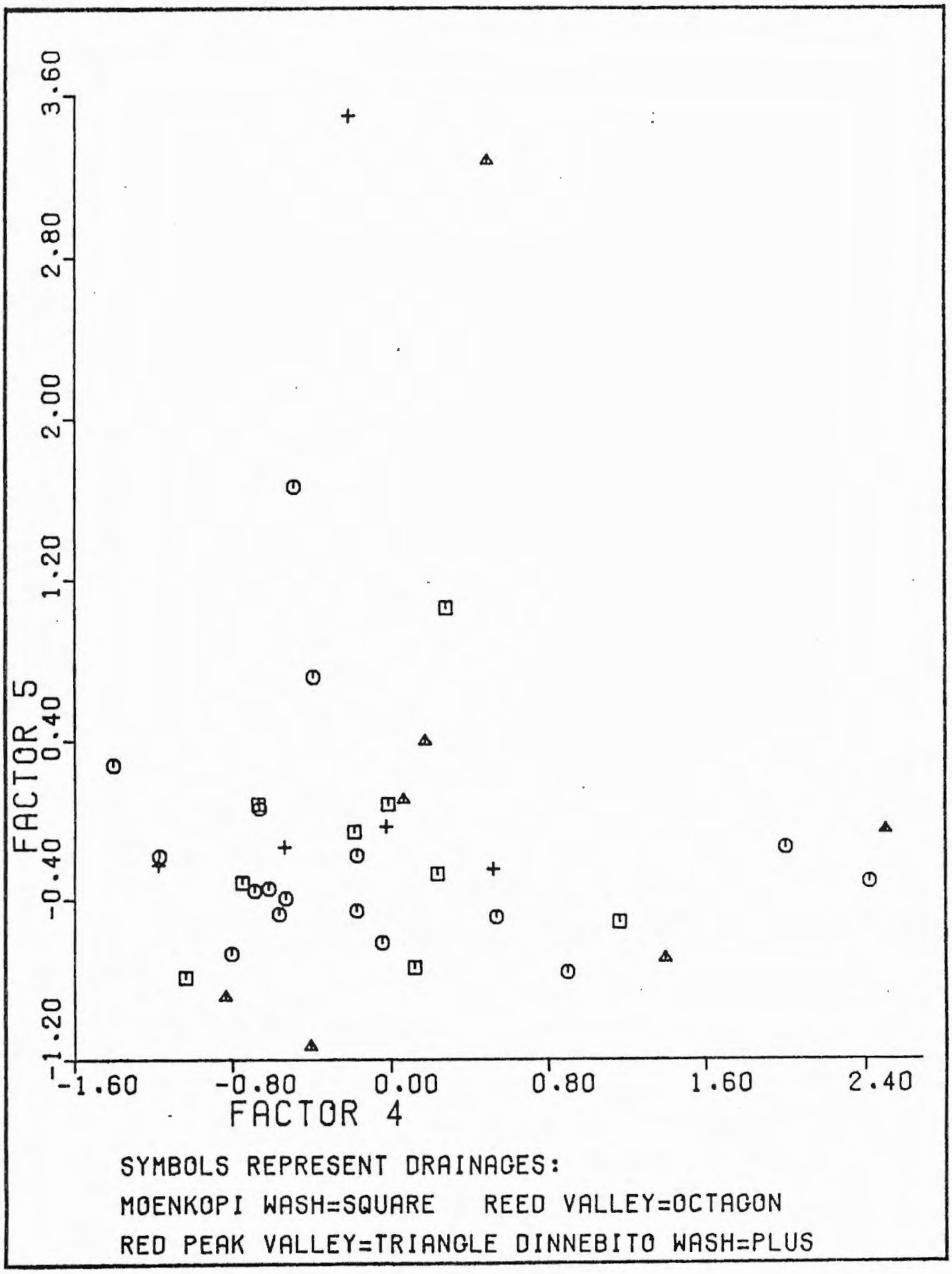


Figure 49. Factor scores for Factors 4 and 5, time period III.

sources in widely separated and opposite directions. As can be seen in Figure 50, six sites have significant positive scores on this factor. Appendix E indicates that four of the sites actually have this combination of materials, so it is a relatively strong pattern. In addition, the six sites are located in all drainages in the study area, which also lends support to the model.

Vitreous petrified wood is associated with white baked siltstone in Factor 7. Most sites have negative scores on this factor, but three of the four drainages are represented among the three sites with significant positive scores (see Figure 51). A single site, D:7:204, from Moenkopi Wash, has high positive scores on both Factors 6 and 7. Inspection of Appendix E indicates that this site has both creamy opaque and vitreous petrified wood, materials available in opposite directions. It is unfortunate that there is only one site that has high significant scores on both of these factors, but it does help support the model.

Oolitic chert alone has a significant loading on Factor 8. Figure 52 indicates significant scores on this factor at Red Peak Valley and Reed Valley sites. Sites from most drainages are divided fairly evenly on this factor.

Fracture-line chert and quartzite have high significant loadings on Factor 9. Again, this is a combination of an import and a local hammerstone material (see Figure 53). In Factor 10, sandstone, alone, has a high loading. Examination of Appendix E indicates that the six sites with high positive scores on this factor all are from Reed Valley (see Figure 54), and three of the five sites with significant negative scores also are from Reed Valley.

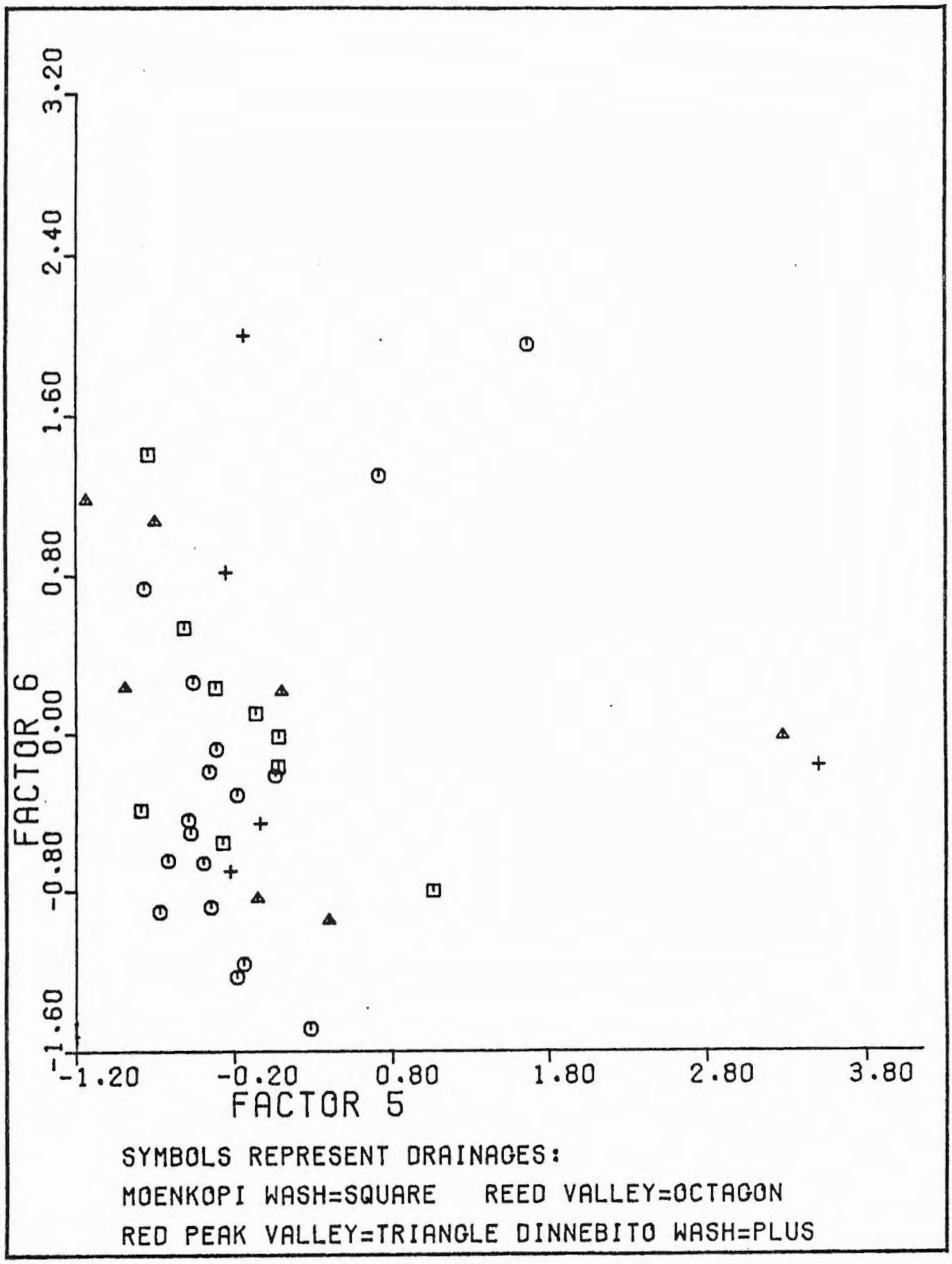


Figure 50. Factor scores for Factors 5 and 6, time period III.

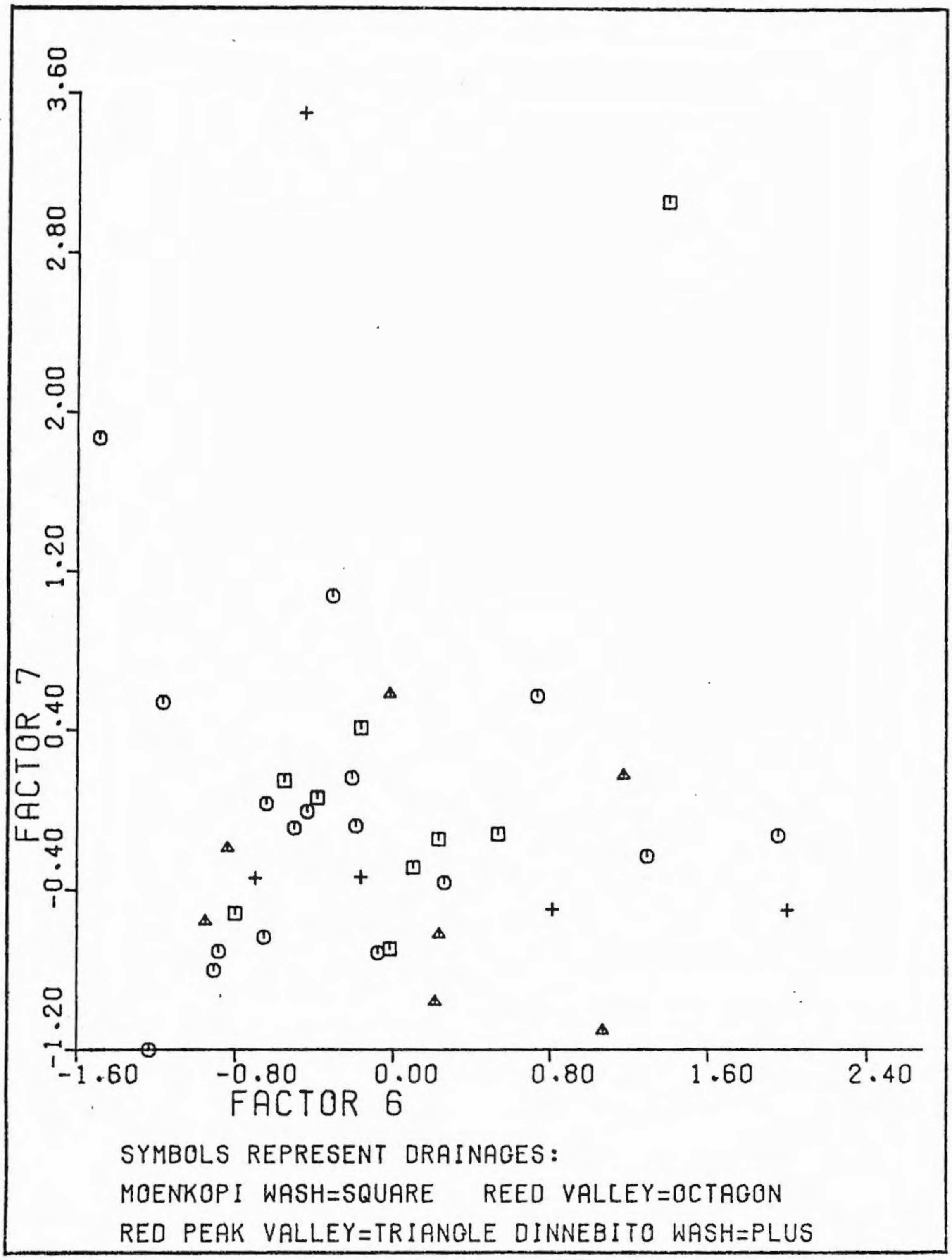


Figure 51. Factor scores for Factors 6 and 7, time period III.

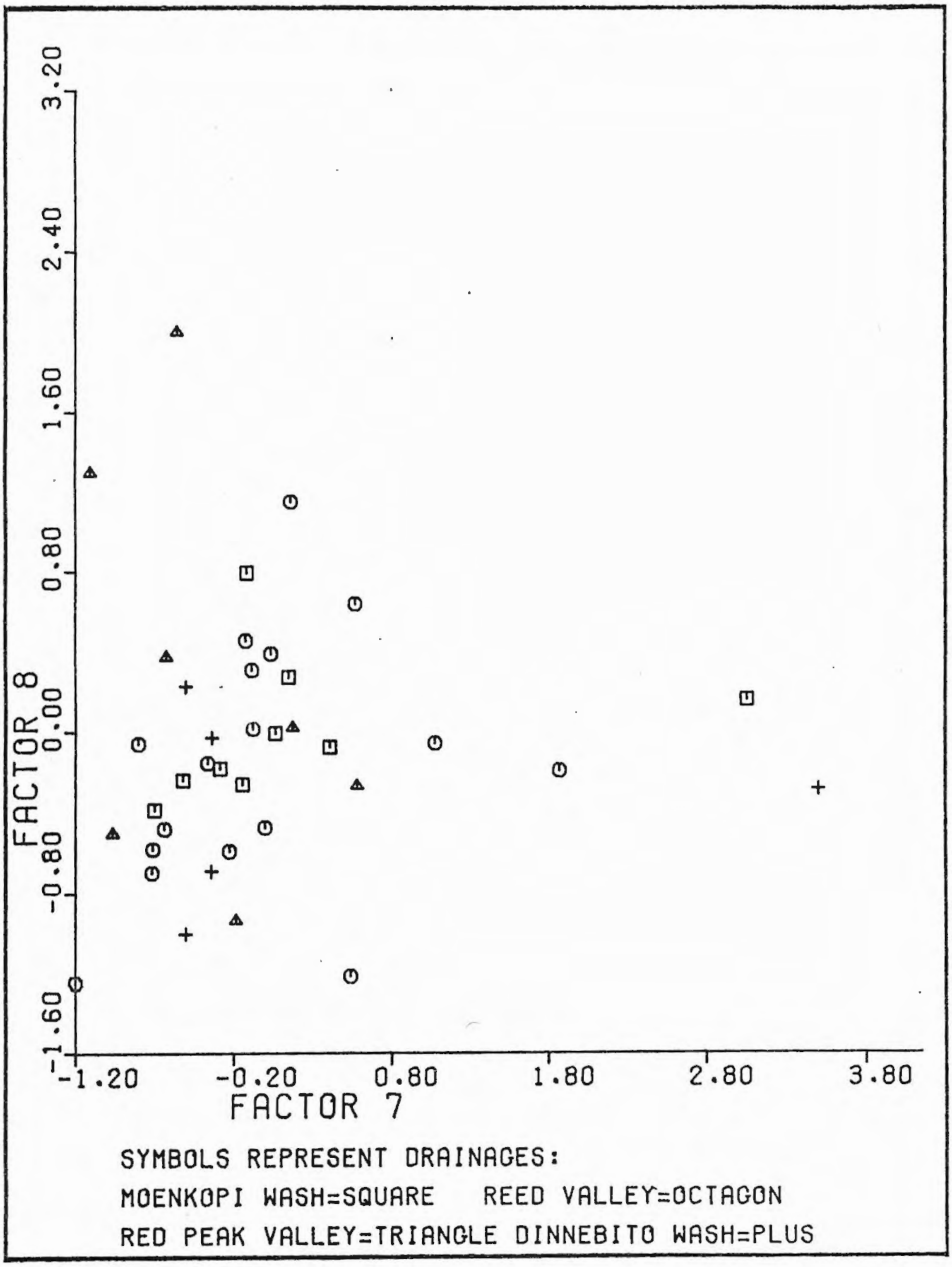


Figure 52. Factor scores for Factors 7 and 8, time period III.

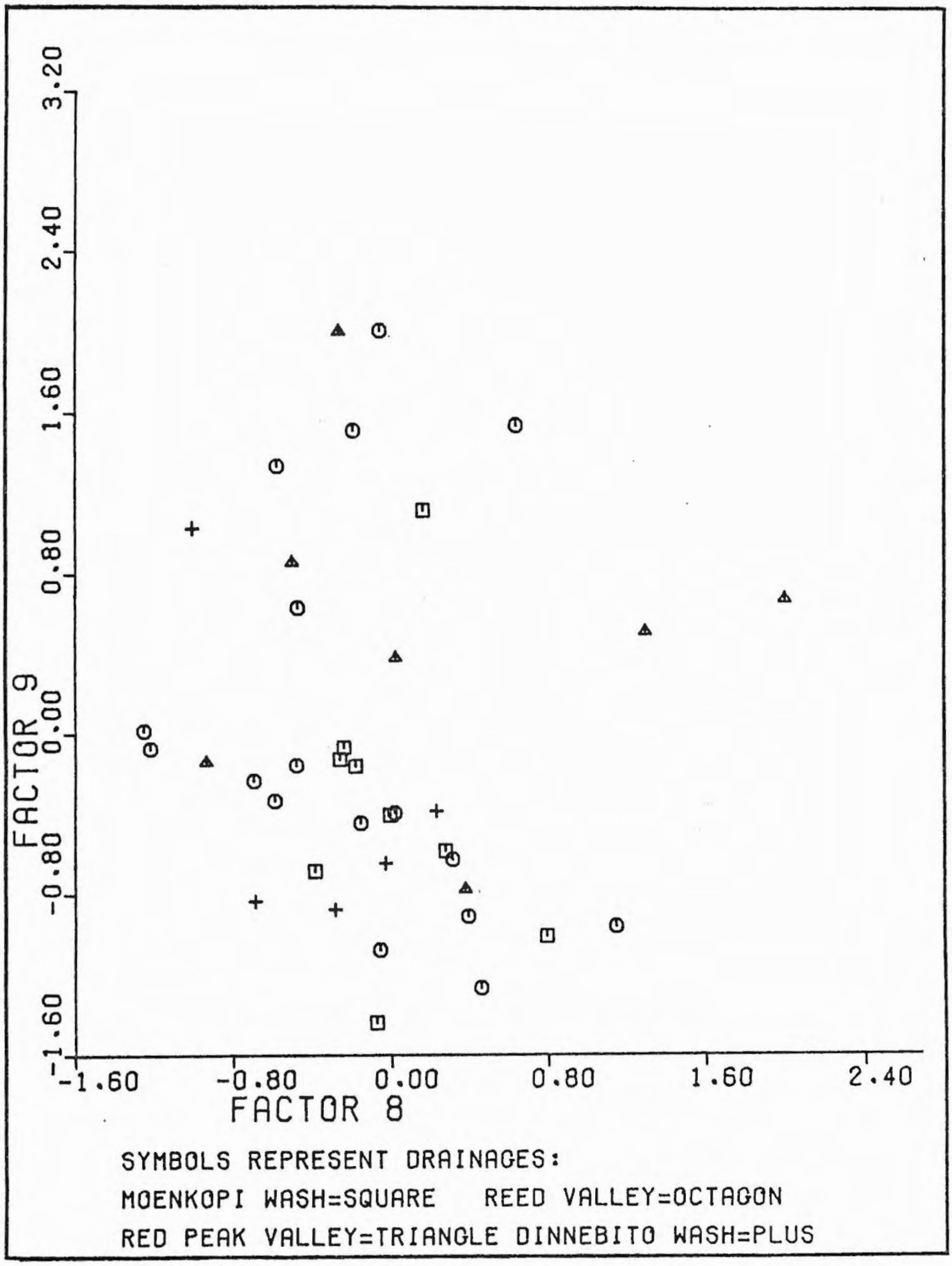


Figure 53. Factor scores for Factors 8 and 9, time period III.

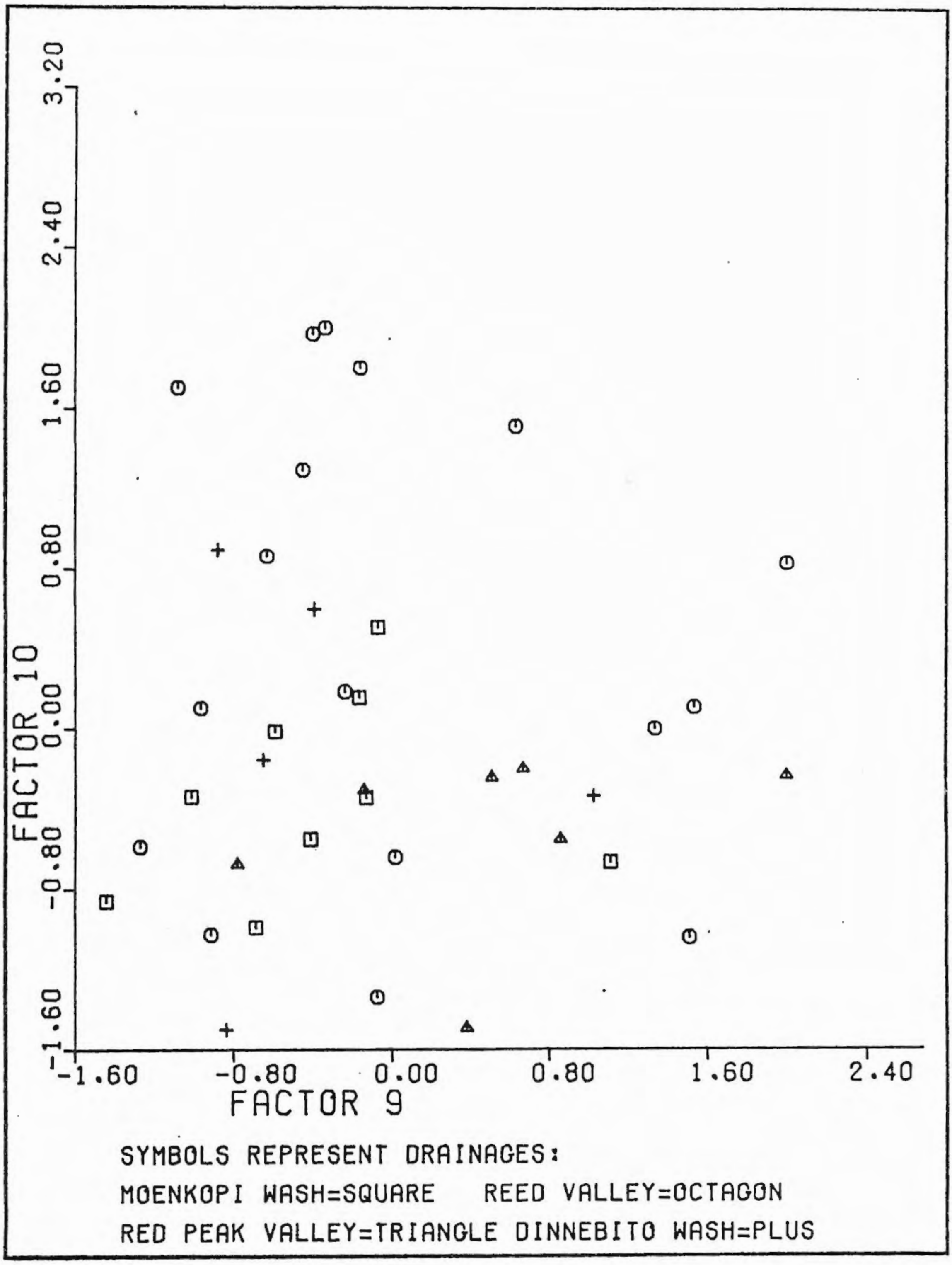


Figure 54. Factor scores for Factors 9 and 10, time period III.

Unlike expectations for time period II, significant factor scores are expected, at individual sites, for factors with nonlocal materials available in opposite directions. The association of Chinle chert and creamy opaque in a single factor supports the model of increased interaction among Black Mesa sites at this time; additional instances of similar circumstances would support it further. Factors 1, 3, 5, 6, 7, and 9 all have materials with sources that have been identified (narrowed down, if not actually found in the field) at some distance from the mesa. With the exception of Factor 6, which has materials available both to the north and to the south, the factors have materials available in a single direction. Significant scores will be inspected, as they were for time period II, to determine if greater sharing of material occurred.

Of the 38 sites, 23 (61%) have factor scores with absolute values greater than 1.00 on at least one of these six factors (see Appendix E). Thirteen of the 23 (57%) have scores greater than 1.00 on only a single factor, so they are omitted from further analysis. These percentages follow predicted trends in that a higher percentage of time period III sites have significant scores (> 1.00) on factors with materials available at great distances (61%) than time period II sites (46%). In addition, a greater proportion of the time period III sites have significant scores on more than one of these factors (43%) than do the time period II sites (31%).

Inspection of Appendix E reveals the actual materials found on each of these sites. Only materials with distant sources in specific directions are critical here. Six of the sites have significant scores on two factors: D:7:205, a Moenkopi Wash site, has obsidian, basalt, and pink chert (N and S); D:11:702, a Dinnebito Wash site, has creamy opaque and Chinle chert (N and S); D:11:510, a Red Peak Valley site, has only Chinle chert (S); D:11:279, also a Red Peak Valley site, has obsidian and fracture-line chert (S and N); and D:11:627 and D:11:630, both from Reed Valley, have none of these materials. Three of the four sites with scores greater than 1.00 on three factors also are supportive: D:11:491, from Reed Valley, has creamy opaque and Chinle chert (N and S); D:11:414, also from Reed Valley, has fracture-line chert and vitreous petrified wood (N and S); D:7:204, from Moenkopi Wash, has creamy opaque and vitreous petrified wood (N and S); and D:11:328, from Red Peak Valley, has none of these materials.

In addition to the four sites mentioned earlier that have the Chinle chert-creamy opaque combination of materials, the model derives support from four more sites (D:7:205, D:11:279, D:11:414, and D:7:204) with new and different combinations of materials having sources in opposite directions. These sites, also, are divided among the drainages and, with the addition of D:11:279, all drainages are represented among these sites.

Factor Analysis Summary

The factor analysis, which grouped the raw materials rather than the sites, has proved very supportive of the cluster analysis results. During time period I (undated and A.D. 793 sites), most raw material use focused on materials available on or near the mesa. Only two of the potential six materials known to be available only at great distances were found on sites dating to this period. Vitreous petrified wood was at one site in Moenkopi Wash, and fracture-line chert was at two sites, one in Moenkopi Wash and the other in Red Peak Valley. Fracture-line chert, although not known to outcrop locally, is available in the Mesa Verde area in a formation that also occurs on Black Mesa, the Dakota Sandstone. It is possible that a local source of this material still may be found. Moenkopi Wash, as pointed out in the section on cluster analysis and in Borger's (1979) analysis, is the area of Black Mesa where trade ties for nonlocal raw materials seem to have developed first.

Forty-three percent of the time period II (A.D. 800-999) sites, as opposed to 10% of the time period I sites, have at least one raw material from a distant source. Expectations that combinations at sites of raw material types should originate in the same direction were not upheld completely, but that trend was apparent. In time period III (A.D. 1000-1150), when raw materials and/or exchange ties were expected to have been shared to the greatest extent, numerous combinations of materials with sources in different directions were found on sites. In fact, two materials from sources in opposite directions occurred together consistently enough to be associated in the same factor. Thus, the trend for increased interaction among Black Mesa sites over time appears to be supported by the chipped stone raw material data.

CHAPTER VI

CONCLUSIONS

This dissertation has had three main ojectives: (1) to identify the chipped stone raw material types used prehistorically on Black Mesa, and to locate general source locales for the material used; (2) to demonstrate the utility of lithic raw materials in an analysis of change over time in interaction intensity; and (3) to test for the increase in interaction hypothesized in recent models of culture change for Black Mesa. The achievement of each of these will be evaluated in the following pages, as will suggestions for future treatment of similar research questions.

The attempt to discern general source locales for the raw materials was, on the whole, very successful. On the average, 95% of the assemblages could be identified as to specific material type. Materials from unknown sources could, in most cases, be identified as to material type (usually chert), even though the bedrock formation from which they originated remained unknown. Source areas for a few of the materials have not yet been determined, and additional work is required on this problem. For example, it has been assumed throughout this dissertation that basalt originates in the same general source area as obsidian, most of which comes from the San Francisco volcanic field near Flagstaff. If the source of basalt is not in the Flagstaff area, the discrepancy should have little effect on the results of the analysis, as basalt occurs in very low frequencies. It should be verified, nevertheless.

Fracture-line chert is another material for which a source still must be located. Dakota Sandstone, the bedrock formation in which it outcrops, forms the bench of Black Mesa. Thus far, however, the only chert pebbles found in the Dakota Sandstone on the Black Mesa bench have been very small. Fracture-line chert also occurs in Mesa Verde site collections. Sources of the material, in pieces large enough for lithic manufacture, have been found there. The source location for the Black Mesa fracture-line chert has to be identified. In this analysis it is crucial to know whether this material was available locally or if it was obtained from sources as distant as Mesa Verde. Collections from intermediate areas (e.g., Monument Valley and Chinle Valley) should be examined for this material.

The problem with identifying specific gravel sources probably will remain unresolved. Even if very detailed work in identifying the fossils that occur in the fossiliferous gravels were completed, it would help to identify not the source of the gravels but only the source of the parent rock from which the gravels were formed. It might be useful to expend more effort in identifyng gravel sources on and near the mesa to assure that the bulk of this material probably was obtained locally.

Finally, sources of the Black Mesa creamy opaque material should be located, or, if this is not feasible, it should at least be chemically analyzed along with samples from Mesa Verde, Hovenweep, and Salmon Ruin to determine if all four areas used the same source. It is, of course, possible that each area used several sources and that there may or may not be overlap between them.

The ideal would have been to locate the particular bedrock outcrops used by Black Mesa populations for each chipped stone raw material, but such detailed analysis was not necessary for my research objectives. Furthermore, the cost of such an undertaking would be prohibitive. Outcrop locations would add a new dimension for future research in that outcrops, rather than formations, could be used as the source locales. In doing so, the number of distinctive sources isolated for analysis would increase substantially, and their locations would be much more precise. Materials that were available locally and at intermediate distances would then become more important in the analysis. The present study assumed that local materials were known to, and shared, by all. Local materials were, in effect, used as a control to demonstrate that area-wide use of some raw materials occurred, in contast to the more restricted use of others. Although it seems to have been the case that sources of the local and intermediate materials were known to all, questions, such as the exact source used, whether or not it was shared, and, if so, by whom, have not been addressed. It would be of interest to determine whether the same sources of Owl Rock chert remained important over time or, more importantly, if sites that shared both Owl Rock and Navajo cherts actually used the same bedrock outcrop of each material. If the latter were the case, it would be taken as an indication of more intense interaction between the two sites.

A major contribution of this dissertation to Kayenta Anasazi archaeology is the source information developed for the identification of many of the chipped stone raw materials used in the region. Raw materials used on Black Mesa have been identified by the author in collections from other areas, including Long House Valley, Mesa Verde, Hovenweep, Walpi, Chaco Canyon, and Chavez Pass. As additional cross comparisons are made it is almost certain that similarities will be found with other areas as well.

The second objective of the study was to demonstrate the utility of chipped stone raw materials in an interaction analysis. The association between artifact and source was, in most cases, done visually and, it is believed, with considerable accuracy. As stated earier, Luedtke's analysis of Michigan cherts (1976) demonstrated an 8.7% discrepancy between the visual analysis and neutron activation analysis. With the combination of different raw materials used on Black Mesa, the error rate is expected to be even lower. The argument was made that visual sorting could not be done with as much confidence on ceramics because the temper, clay, and paint all have the potential for separate sources (this does not even consider the effect of the strictly human element, the design style). One shortcoming of the method may be the need for chipped stone assemblages with large numbers of diverse materials and it may have been fortuitous that it was tried first on the Black Mesa data. In an area with less variety of chipped stone raw materials some form of chemical analysis may be more important to differentiate among outcrops rather than merely associating raw material types with their formations.

Regardless of the means necessary to source the materials to the required level of precision, it is argued that the methodology provides information at which a traditional source analysis only hints. In a traditional source analysis, that treats only a single raw material type, an unlocated intervening source may be argued to be the cause for an anomaly in the distribution. In this analysis, not only is the intervening source known, but the distribution of that material on sites is known as well. The relative importance of the two materials in different assemblages is known, as is the extent to which they occur together at sites. Combinations of raw materials are necessary to do a study of interaction. Study of a single material will provide information only about the use of that material and conjecture about the rest of the assemblage. To use a specific example from this analysis, if creamy opaque had been the only material studied, its absence at early sites would have been noted, as would the increase in its use over time. However, the combination of Chinle chert, available only to the south, with creamy opaque at late sites would have been missed, and that relationship is a critical factor in the argument about interaction among Black Mesa sites.

It is only by developing data sets such as this that exchange models such as the one proposed by F. Plog (1977) can be employed. In Plog's model, variables such as directionality of exchange are emphasized and information on both ends of the exchange network is needed to be able to evaluate the model adequately. These data, then, should help in studying the connectivity within and between study areas in the Kayenta region (and beyond).

The final goal of the dissertation was to test the hypothesized increase in interaction among Black Mesa sites. Several of the Black

Mesa culture change models discussed earlier suggest an increase in interaction over time. In fact, S. Plog (1978b) and Nelson (1978) hypothesize a situation of hypercoherence in which inhabitants of different sites become so dependent upon one another that stress felt by people at one site would be transmitted quickly to others. This organizational problem has been related to subsistence stress, population density, and possibly detrimental environmental change and is felt to be the cause of the abandonment of northern Black Mesa.

The interaction hypothesis was examined first through a series of cluster analyses that grouped sites based on similar percentages of chipped stone raw materials. A dramatic change occurred over time from an emphasis on the use of baked siltstone at the early sites, to a variety of materials, mainly cherts and hammerstone materials, at the post A.D. 800 sites. The magnitude of the change was such that it supports the notion that the mesa was not continuously occupied, but that a gap exists in the occupation (Ware 1976). Explanations for this shift will be offered below but must first be tested prior to acceptance.

Two overarching models could be employed to account for change over time in raw material use. The major difference between them is whether the mesa was occupied the year around or whether there was only seasonal (summer) occupation during the early periods (Powell 1980).

If the mesa had been occupied the year around, beginning in Basketmaker times, then the Black Mesa lithic assemblages represent the entire lithic industry for the population. Since they are composed almost completely of baked siltstone, this indicates almost complete dependence by the population on a single raw material type for the performance of all chipped stone raw material functions. The few nonlocal raw materials in the assemblages (with two exceptions) were from sources located in the valley below the mesa. The nonlocal materials used were Navajo chert and Owl Rock chert; fracture-line chert and vitreous petrified wood were the exceptions but they were present at only three sites at this early time. Thus, under this model it would appear that sites occupied during the Basketmaker period, which had the lowest population density, also had the least developed system of external ties.

This explanation runs contrary to the findings of Fernstrom (1980) and Hardy et al. (1980). They found that the geographical extent of exchange systems for chipped stone and redware ceramics contracted as population density increased. Their findings may be understood in terms of Wobst's (1974) model of the minimum number of interacting persons necessary to maintain a viable marriage network for the biological continuance of the population. Although neither of these studies treats sites dated earlier than A.D. 800, the general model still should hold.

The other factor suggested by this model is that the need for chert was not primarily because of its utility as a chipped stone raw material. A description of the utilized material on Black Mesa sites has not been provided here, but, like many Southwestern assemblages, the tools generally are not formalized. Flakes are the most commonly utilized form (in contrast to formal tools), and a wide variety of materials are used for a wide variety of functions. If (1) the entire Basketmaker repertoire of stone tools is present on Black Mesa, and

(2) the range of activities did not change over time, and (3) white baked siltstone was the material used to manufacture all tool types, then (4) the introduction of cherts in large proportions in the later assemblages was not purely for technological reasons. The validity of (1) is not presently known because we do not know whether the mesa was occupied the year around. If the mesa was occupied the year around, (2) should be true, as agriculture was practiced at the earliest sites in conjunction with hunting and gathering. Baked siltstone could have been used for all except the larger tool types, as it fractures conchoidally and produces a sharp cutting edge. However, it occurs only in small pieces, so larger tools such as choppers would have to have been manufactured from another material. Proposition (4) then remains to be tested, but it does derive support from the ability of the populations to refocus on locally available materials at the end of the sequence.

Thus, under this model, Basketmaker populations had little outside contact, and exchange ties broadened as population increased. They contracted again when the system began to break down and the mesa was being abandoned. Alternately, if early Black Mesa populations were sufficiently mobile that they spent only the summer months on Black Mesa and the winter months elsewhere (Powell 1980), several factors may have contributed to the composition of the chipped stone assemblages. The most obvious factor is that we may be seeing only a part of the range of raw materials used by these people, namely those available on Black Mesa. In a truly expedient technology (Binford 1976), raw materials would be collected and used as needed. Since cherts are available in the valley below the mesa, they may have been relied upon for the manufacture of lithics needed for task completion in that area. The distinctions are not absolute, however; some cherts have been found on early Black Mesa sites, and baked siltstone artifacts have been found on Long House Valley sites (Czaplicki 1977).

Baked siltstone comprised a mean of 20% of the assemblages of the seven Long House Valley sites studied by Czaplicki. The three Basketmaker sites each had 30% or more of their assemblages composed of baked siltstone, principally the white variety. Dating of the other site was less certain, and several of them may be early sites as well.

Certain materials may have been preferred in the manufacture of tools for specific tasks. Pronounced differences among raw material proportions would be observed if the activities in which they were used were seasonally determined. Furthermore, the nonlocal component of the Black Mesa lithic assemblages may have been curated (Binford 1976). In this case, mainly broken tools and a few lost ones would remain and the majority of the assemblages would be composed of local, expediently used pieces and debitage.

In this second model, the imported materials may have been desirable for superior working qualities but may have functioned to maintain social ties as well. If Powell (1980) is correct about the early mobility, then Black Mesa populations prior to A.D. 950 would have interacted with others in the region as a matter of course. Hunting and gathering territories probably overlapped, and there may have been institutionalized interaction with a larger group on a seasonal basis. They almost certainly would have had to exchange mates with other groups due to low population density (Wobst 1974). As dependence on agriculture increased (if it ever did) and/or there was increased sedentism, these meetings with other groups may not have occurred with as much regularity. This is not to imply that ties with these people were any less critical--just that they may not have occurred without some impetus. Food shortages would have created a need for interaction and sharing, but in times of plenty these relationships needed to be maintained.

Chipped stone raw materials have several characteristics that make them well suited for this form of exchange. Generally they are abundant at their sources and are available the year around (regardless of season or adverse climatic conditions). They have limited distributions; thus ownership can be recognized. They may be replaced by locally available materials in the event the exchange breaks down or no longer is needed. The latter might have occurred if, as has been suggested, Black Mesa populations reverted to hunting and gathering and reestablished ties in that manner.

Although these models require further testing, the second model, that of seasonal occupation of the mesa prior to about A.D. 950, appears to be more suited to the data. The almost exclusive reliance on white baked siltstone, which is available only in very small pieces, is a feature of the year-around occupation model, which is hard to accept. The evidence of low frequencies of the cherts available in the valley below demonstrates the population's knowledge of the qualities of the materials and the means to obtain them, which makes the low frequencies harder to accept. The reciprocal evidence of baked siltstone from Long

House Valley sites, particularly during the Basketmaker period, provides additional support for the mobility model.

The paucity of rare imports at the A.D. 800-899 sites suggests that, even if the mesa had been reoccupied beginning at about this time, the populations did not arrive with developed exchange ties for these materials. Instead, they developed gradually, beginning with a single occurrence of a rare import at a single site, then perhaps at two sites, and so on. A small number of sites had multiple rare imports, but these were from sources in the same direction. During the later periods many sites had multiple rare imports with sources in different directions. It was only after A.D. 1000 that sites on Black mesa shared widely in the exchange of rare imports, in most cases available only at great distances. Differing combinations of these rare imports become apparent at sites all over the mesa. This pattern was accepted in support of the hypothesized increase in interaction because of the unlikelihood that each of the sites developed these exchange ties independently. The period between A.D. 1000 and A.D. 1100 was one of population growth and the spread of population to all parts of the study area, probably on a year-around basis. It was, in other words, the time when the hypothesized situation of hypercoherence should have been developing if it was a contributing factor in the abandonment of northern Black Mesa. After A.D. 1100, when the breakdown of the system supposedly was occurring and there was an increased emphasis on hunting and gathering, the use of nonlocal chipped stone raw materials declined. Certain types were entirely absent from assemblages for the first time in several hundred years, and others declined in frequency relative to the local materials.

The cluster analysis, then, was very useful in outlining the major patterns.

The factor analysis was used to group the raw material types rather than the sites. All of the raw materials were employed individually in this analysis instead of using the combined frequency categories used in the cluster analysis. In this way, the factor analysis program grouped the materials, rather than having the input data already grouped on the basis of source direction by the author.

The results of the factor analysis supported those of the cluster analysis very well. The same change over time was observed, as was the importance of the Moenkopi Wash area in the chipped stone exchange. During the first two time periods (undated and A.D. 793, A.D. 800-999), only single rare imports (combined with local and/or intermediate materials) or rare imports with sources in the same direction were grouped together in factors. During the latest period (A.D. 1000-1150), two materials with sources in opposite directions were grouped in a factor. Factor scores were used to denote when sites had rare imports from the same or different directions and the patterning found supported the hypothesis of increased interaction. Because the last time period used in the factor analysis extended from A.D. 1000 to A.D. 1150, the decline in imports at the very end of the sequence was not observed.

This research has important ramifications for Black Mesa archaeology in that it has begun to test one critical aspect of several models that have been proposed and remained essentially untested for several years. The results strongly suggest that inhabitants of Black Mesa sites did not act in isolation and, in fact, as time went on, became increasingly involved with one another.

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APPENDICES
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